COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

February 1959

Allen Station of the Duke Power Company is now using its own flyash for concrete. Story on p. 38.

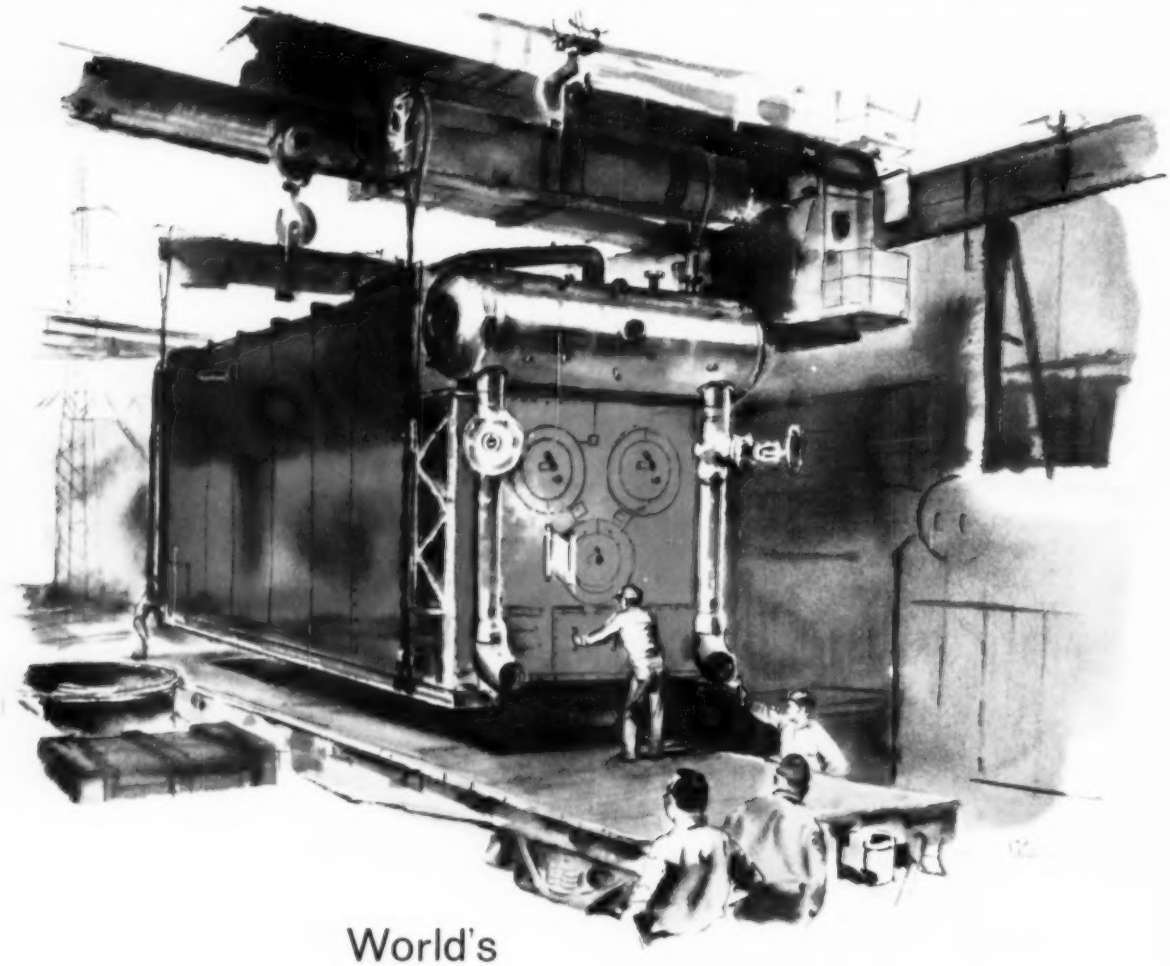
Flyash in Concrete

Pump Clinic

Coal and Oil Slag Studies

Utilizing Incinerator Heat

"CREATIVE ENGINEERING" PROVIDES NEW TYPE OF PACKAGE BOILER TO MEET TODAY'S STEAM NEEDS



World's highest capacity Package Boiler removes traditional space and performance limitations

The flat car pictured above is carrying an engineer's dream. It's a space-saving steam generator which makes electric utility performance standards available to industrial plants. It's a unit of large capacity—yet it's factory-assembled and ready to be installed as a one-piece "package." It's a product which reflects C-E's record of developing steam equipment that introduces new standards of performance.

For the first time, here's a boiler capable of producing over 100,000 pounds of steam every hour . . . and at pressures and temperatures previously unobtainable in a 'packaged' unit. These results are made possible by utilizing *C-E Controlled Circulation*, the most notable development of this decade in the field of large utility boilers.

In short, here's a new alliance of performance with economy. This is what progressive management demands of its capital equipment. This is what you can count on *Combustion* to deliver.

"CREATIVE ENGINEERING" is the reason for the leadership attained by C-E products. The products which bear this mark of leadership include:

all types of steam generating, fuel burning and related equipment · nuclear power systems · paper mill equipment · pulverizers · flash drying systems · pressure vessels · soil pipe

COMBUSTION ENGINEERING

Combustion Engineering Building, 200 Madison Avenue, New York 16, N. Y.

C-187

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 30 **No. 8**

February 1959

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COMBUSTION publishes its annual index in the June issue and is indexed regularly by Engineering Index, Inc. and also in the Applied Science & Technology Index.

The magazine is now reproduced and distributed to libraries on microfilm by University Microfilms of Ann Arbor, Michigan.

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Published monthly by COMBUSTION PUBLISHING COMPANY, INC., 200 Madison Ave., New York 16
A SUBSIDIARY OF COMBUSTION ENGINEERING, INC.
Joseph V. Santry, Pres.; Charles McDonough, Vice-Pres.; Otto Strauss, Treas.; Thomas A. Ennis, Secy.
COMBUSTION is sent gratis to engineers in the U. S. A. in charge of steam plants from 500 rated boiler horsepower up; and to consulting engineers in this field. To others the subscription rate, including postage, is $4 in the United States, $5.50 in Canada, and $8 in Latin America and other countries. Single copies: Domestic, 40 cents, Foreign, 60 cents plus postage. Copyright 1959 by Combustion Publishing Company, Inc. Publication Office, Easton, Pa. Issued the middle of the month of publication.
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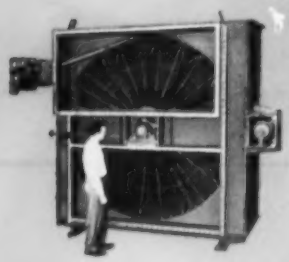
BPA

Printed in U. S. A.

Here's what you can do about the high cost of fuel



Get the same heat from less fuel with a

Ljungstrom® Package Air Preheater

A significant amount of your fuel is used to heat the combustion *air* in your boilers. A Package Ljungstrom Air Preheater raises the temperature of combustion air by recovering the heat from the exhaust gas. In preheated air, the fuel you are now using will burn more completely, and much more of it will be *productive* heat.

Here is an example of what this means in dollar savings. In one year (1956) a typical Package Ljungstrom installation saved $17,600 in fuel costs. In some installations the Package Ljungstrom saved enough fuel to pay for itself in two years.

Compact Package design of the Ljungstrom gives you all the advantages and economies of the Ljungstrom in a preassembled unit. The Package Ljungstrom is available in vertical or horizontal models that are readily adaptable to any plant arrangement.

For further information, write today for the free 14-page Package Ljungstrom manual.

THE AIR PREHEATER CORPORATION

60 East 42nd Street, New York 17, N. Y.

This 75,000 square foot condenser pre-assembled and pre-fitted at Maryland was shipped in 5 compact maximum rail clearance sections.

5-piece Maryland condenser design

Horizontal division separates the neck section (1). The main body of the condenser is divided both vertically and horizontally, as shown by sections numbered (2), (3), (4) and (5).

Maryland's 5-Piece Condenser

Designed for Low Cost Field Erection

Maryland designed, built, pre-fit and pre-assembled this 75,000 square foot condenser in five compact sections for accurate and low cost field erection.

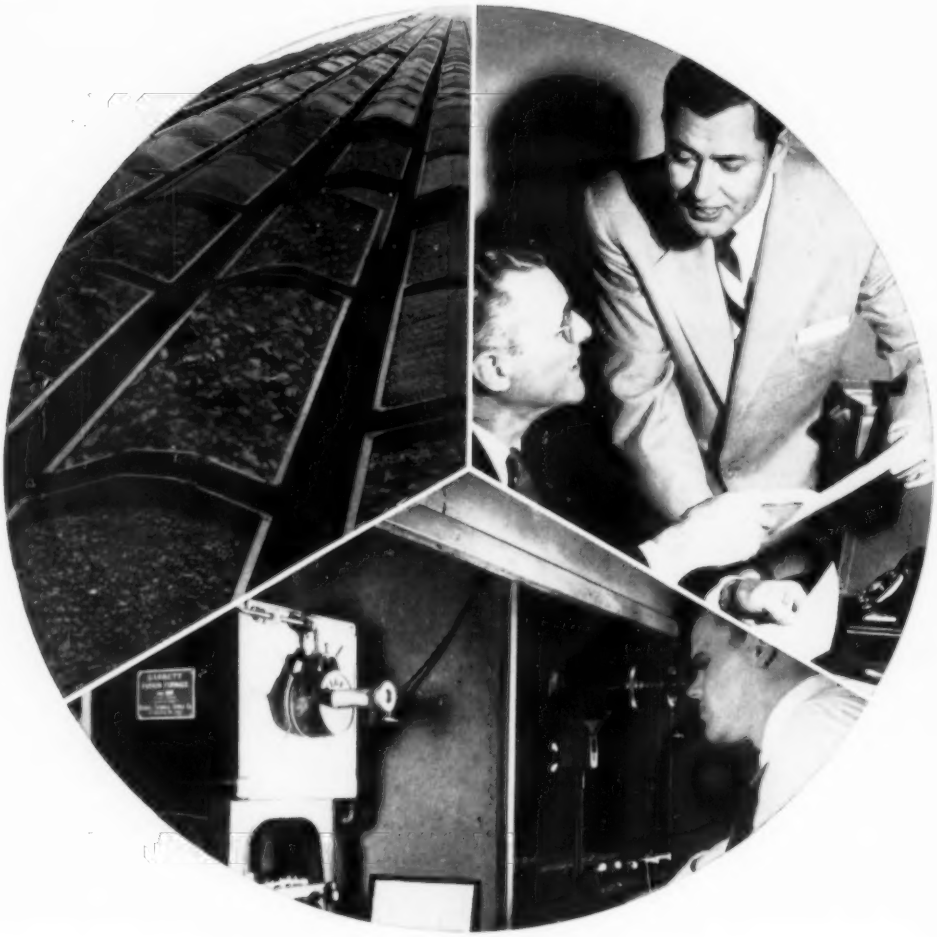
Now being installed at Reesedale, Pennsylvania in West Penn Power's Armstrong Station, this unit indicates Maryland's ability to engineer and build large surface condensers for electric utilities. It will condense 812,819 pounds of steam per hour exhausted from a 156,250 KW Westinghouse turbo-generator, and its full deaerating hotwell will produce condensate with no more than .01 cc of oxygen per liter.

When *your* plans call for steam surface condensers, consider the advantages offered by Maryland's years of engineering experience and facilities for designing and manufacturing condensers, of any size.

Industrial Products Division

MARYLAND SHIPBUILDING & DRYDOCK COMPANY

BALTIMORE 3, MARYLAND • *Representatives in Principal Cities*



BEACON COALS FOR ELECTRIC UTILITIES,
Industrial and Commercial Uses

Here are some facts that may interest you — as a buyer of coal for power plant use — when you are seeking a dependable source of supply.

Our yearly productive capacity is in excess of 19,000,000 tons. We can meet tonnage requirements of the largest user, and adhere to the strictest time-table on shipments.

We produce, in our fifteen active mines, a variety of coals with a complete range of analyses. We can thus satisfy the most exacting specifications . . . and furnish the fuel best suited to your particular combustion equipment.

We maintain a central coal laboratory, supplemented by quality control labs at each of our larger mines. This assures conformity to standards.

Our representatives are trained combustion men, who can understand your needs, and work intelligently to meet them. Inquiries and follow-ups are expedited by our teletype network, which connects sales offices with all our major mines.

Doesn't it seem reasonable to think that our *product* plus our *service* can bring you something extra in filling your fuel needs? We'd like to demonstrate that it can.

EASTERN GAS AND FUEL ASSOCIATES
BEACON COAL

EASTERN GAS AND FUEL ASSOCIATES

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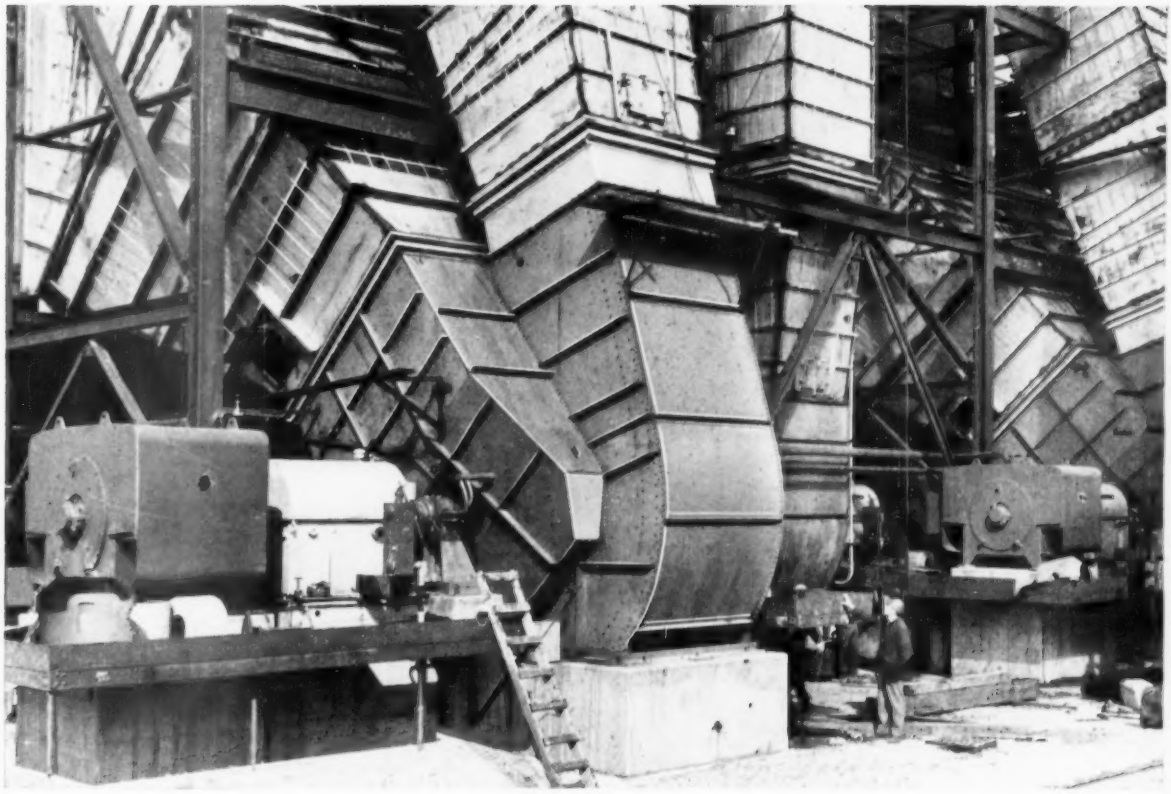
For Export: CASTNER, CURRAN & BULLITT, INC.



LOOKING FOR PEAK EFFICIENCY OVER BROAD RANGE FOR YOUR DRAFT FANS?

Here's Why "Buffalo" "BLH" is Best Answer:

The "Buffalo" Family of "BLH" Fans is designed for highest mechanical efficiency over an extremely broad operating range. Peak efficiencies are up to 86%. Rugged "Buffalo" construction insures economical, dependable operation throughout a long, trouble-free life.

"Buffalo" Type "BLH" features include: streamlined housing designed to deliver ultra-smooth air flow, peak static conversion and pressure distribution at outlet — turbulence minimized by smooth inlet bell, directional inlet vanes, backward-curved blades, matching rotor flange and inlet bell and gradually divergent outlet. These features all add up to the quiet, powerful, smooth performance characteristic of the "BLH".

Reliable, maintenance-free operation is the result of extra-heavy construction throughout. This includes sturdy steel plate construction ruggedly welded for extra strength — oversized shafts and bearings. Rotors are statically and dynamically machine balanced at factory.

If your mechanical draft conditions require a dependable fan that provides high efficiency over a broad operating range, ask your "Buffalo" engineering representative for complete facts about the "Buffalo" family of mechanical draft fans. Or you can write us direct for Bulletin FD-905.

"Buffalo"

BUFFALO FORGE COMPANY
Buffalo, N. Y.

Buffalo Pumps Division • Buffalo, New York
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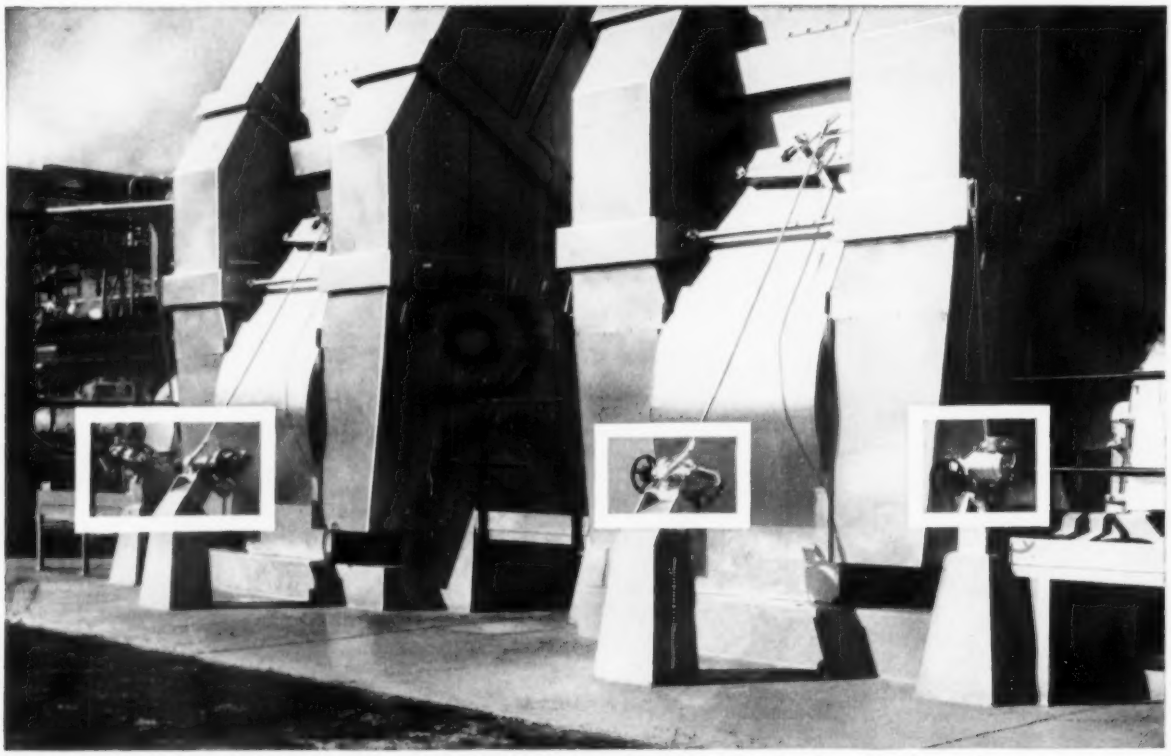
VENTILATING • AIR CLEANING • AIR TEMPERING • INDUCED DRAFT • EXHAUSTING • FORCED DRAFT • COOLING • HEATING • PRESSURE BLOWING



Induced draft fan louvers are controlled by outdoor-mounted Metermax drive units shown above.

HERE'S HOW TO GET

reliable drive unit operation-Outdoors

Metermax Electric Drive Units operate in outdoor locations in spite of snow, sleet, driving rain, and summer sun. They position fan louvers, vanes, dampers, mill feeders, or any other controlled element. And they never quit as long as you give them power.

There's no need for expensive air dryers, jackets, or weather shelters; the units drive in any kind of weather—RARE—and give you continuous, accurate positioning.

At all times, electric drive units provide the instant response necessary for closely coordinated action in large central stations where controlled elements are widely separated.

As for dependability—these drive units operate for long periods with only routine lubrication. Many have been in continuous service—indoors and outdoors—for more than 15 years.

These specific features may interest you:

Self-locking double worm-and-gear drive. *There's no chance of trouble from backdriving. And no locking devices are needed.*

Self-releasing effect of worm-and-gear *permits resumption of remote manual control immediately on restoration of power . . . you don't have to unlock or reset the individual units.*

Simple remote control. *You transfer quickly from automatic to remote manual control by simply turning the control station handle; there's no reset fuss to bother with.*

Compact, functional control station arrangement. *Because the electric control stations require no piping, a close, functional grouping with other motor controls is possible without losing back-of-panel accessibility.*

True position indication. *You always know precisely the position of your controlled elements; electric indicators respond only to actual movement, independent of friction or sticky dampers.*

Low maintenance. *These units have no packing glands, stuffing boxes, or pilot valves. Your maintenance chores are minimized.*

Standard sizes. *Whether for 25 or for 2500 pound-feet, all torque requirements are fully met by these standard drive units.*

If your control needs would be better served by these electric drive units, why not write us about your specific applications? Address us at 4972 Stenton Avenue, Philadelphia 44, Pa.

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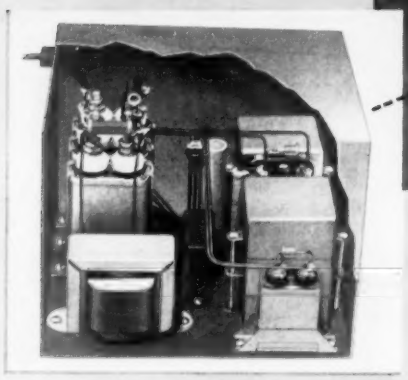
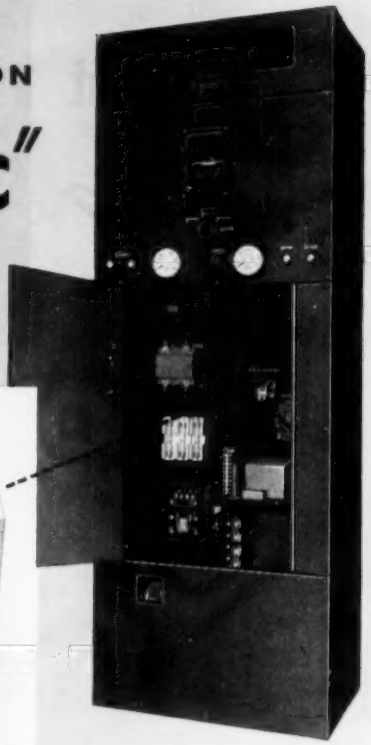
THE WESTERN PRECIPITATION

"Transistomatic" CONTROL





BY FAR, the Industry's Most Advanced Precipitator Control...

NO TUBES! NO RELAYS! NO COUNTERS!

and carries a Lifetime Guarantee!

In the electrostatic precipitation of dust, fume and fly ash, no installation is completely modern without *automatic* control to maintain optimum Precipitator efficiency as the characteristics of the gas stream fluctuate. Compared with manual control, automatic control is not only more sensitive and more efficient, but actually costs less because of the vital savings it makes in labor and operating costs . . . *savings so important that no profit-minded operator will want to be without them.*

But the important point to remember is this—
Although many manufacturers of precipitation equipment offer units for precipitator automation, no other unit is equal to the "Transistomatic" Control for foolproof simplicity, rugged dependability or control accuracy!

These are not idle claims. They can be easily verified by making your own comparison . . .

A DESCRIPTIVE BOOKLET
that gives further information will gladly be sent on request. Write, wire or phone our nearest office!

Compare ACCURACY! The "Transistomatic" does not base its "sensing" action on spark *frequency* alone—or spark *intensity* alone. Instead, it continuously integrates BOTH frequency and intensity to establish an overall "power value" that provides a new standard of control accuracy!

Compare DEPENDABILITY! The "Transistomatic" unit contains no parts of any kind requiring regular replacement. Moreover, the entire unit is completely sealed—moisture-proof and watertight.

Compare GUARANTEES! The "Transistomatic" is so foolproof and trouble-free it carries *a lifetime guarantee!*

BEFORE YOU BUY ANY automatic precipitator control, be sure to get the complete "Transistomatic" story. A folder is available giving additional data. Or see your nearest Western Precipitation representative for further details!

WESTERN
PRECIPITATION
CORPORATION

Engineers and Constructors of Equipment for Collection of Suspended Material from Gases and Equipment for the Process Industries

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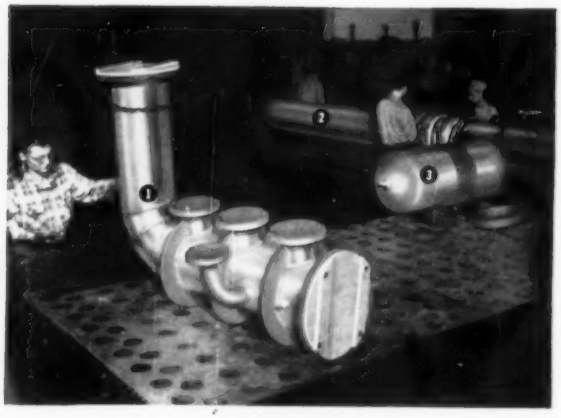
Precipitation Company of Canada Ltd., Dominion Square Bldg., Montreal

ALL IN A DAY'S WORK at *Pittsburgh Piping*



These three jobs are typical of the wide variety of custom piping work which we do for the power and process industries. In the background of the photo welders are shown making the heli-arc root pass on 18" O.D., 3.875" wall, chrome-moly main steam piping. In the foreground, ready for final inspection, is a 12" header for a process operation, fabricated of ⅜" aluminum alloy. The pressure vessel, of austenitic steel, is one of many we produce for atomic energy application. The manufacturing of this type of piping requires specialized facilities . . for engineering, fabricating, testing, assembly, and erection. We have those facilities. Use them on your piping jobs.

Promoting Progress ***IN POWER AND PROCESS PIPING***

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from any angle...

BOILER WATER LEVELS ARE EASIER TO READ with YARWAY INDICATORS

No matter where you stand, you can see at a glance your boiler water level in the Yarway Remote Liquid Level Indicator. The clear, "wide vision" face permits easy readings from any point in a 180° arc.

Readings are instant and accurate because the operating mechanism is actuated by the boiler water itself—by the pressure differential between a constant head and the varying head of water in the boiler drum. Pointer mechanism is never under pressure.

Yarway Remote Indicators are available fully compensated for every change in boiler temperature and pressure and they can be connected to Electronic Secondary Indicators or remote Hi-Lo Alarm Signals (lights or horns), located at any other point in the plant. Also available, Yarway Recorders working on same simple principle.

Over 12,000 Yarway Remote Indicators already installed.

Write for full details on Yarway Indicators for boilers, heaters and other applications. Bulletin WG-1824 tells all, shows typical hook-ups.

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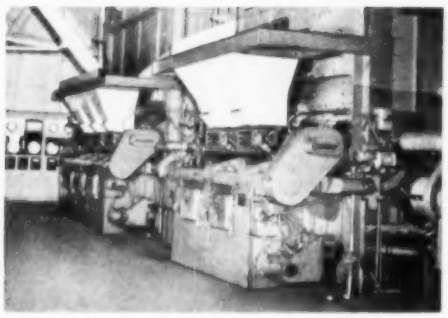
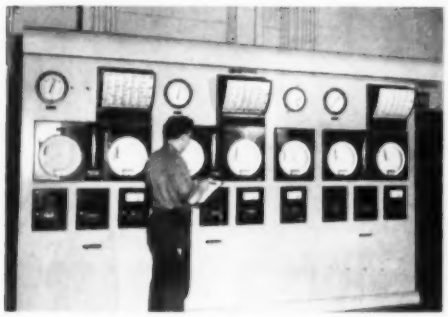
YARWAY

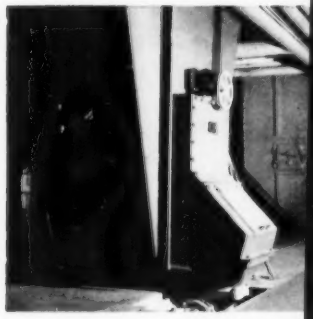
...a good way to specify remote liquid level indicators



Shown are two of the three Keeler boilers— fired by Detroit Spreader Stokers— in the power plant. At the right is the 22,000 lb/hr boiler. In the background is one of the 50,000 lb/hr boilers. The two sizes allow flexibility in operation for widely varying load requirements.



Control panel by Hays Corporation. This system regulates all operations of the boilers—steam pressure, draft, flue gas temperature, banking periods etc.—to give complete, automatic control of steam generating operation.



Ash disposal system, by United Conveyor Co., in basement of boiler room. Ash is removed from furnace by Detroit CC grate, and is taken by vacuum to silo.

Telephone manufacturer calls for coal

Automatic Electric Co. burns coal in new plant because of cost and availability

Modern facilities, modern products, modern fuel—you'll find all three at the new Northlake, Ill., plant of Automatic Electric Co., manufacturing subsidiary of General Telephone. The power house of this communications equipment plant (designed and built by The Austin Company of Cleveland) is as modern and efficient as the manufacturing process itself. The plant required large quantities of economically and reliably produced steam for process work and heating. The fuel selected was *coal*, because of coal's economy and abundant supply. As a result, today Automatic Electric enjoys dependable, low-cost steam.

Coal is lowest-cost fuel

Today, when the annual cost of fuel often equals the original cost of the boilers, you should know that bituminous coal is the lowest-cost fuel in most industrial areas. And modern coal-burning equipment gives you 15% to 50% *more* steam per dollar, while automatic operation trims labor costs and eliminates smoke problems. What's more, tremendous coal reserves and mechanized mining procedures assure you a constantly plentiful supply of coal at stable prices.

Technical advisory service

To help you with fuel problems, the Bituminous Coal Institute offers a free technical advisory service. We welcome the opportunity to work with you, your consulting engineers and architects. If you are concerned with steam costs, write to address below or send coupon. Ask also for case histories booklet, complete with data sheets. You'll find them informative.

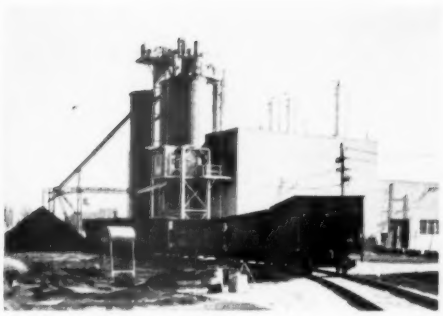
Consult an engineering firm

If you are remodeling or building new heating or power facilities, it will pay you to consult a qualified engineering firm. Such concerns—familiar with the latest in fuel costs and equipment—can effect great savings for you with the efficiency and economy of coal.

BITUMINOUS COAL INSTITUTE

Department C-02, Southern Building, Washington 5, D. C.

See our listing in Sweet's



Exterior view of Automatic Electric power plant. Coal drops into track hoppers; then Stephens-Adamson conveyors move it up into coal silos. Silos have 5-carload capacity.

SEND COUPON FOR NEW "Guide Specifications for Underfeed Stoker Fired Low-Pressure Heating Plants." Heavy demand for the first edition of this booklet, adaptable for design loads 5,000 to 26,000 EDR steam, has justified an expanded edition covering application of underfeed stokers to firetube, watertube and sectional cast iron boilers. Complete specifications criteria cover all aspects of typical heating plant.

Bituminous Coal Institute, Southern Building, Washington 5, D. C. C-02

Gentlemen: Please send me:

☐ Guide Specifications Booklet ☐ Case histories on larger plants
☐ I am interested in your advisory service

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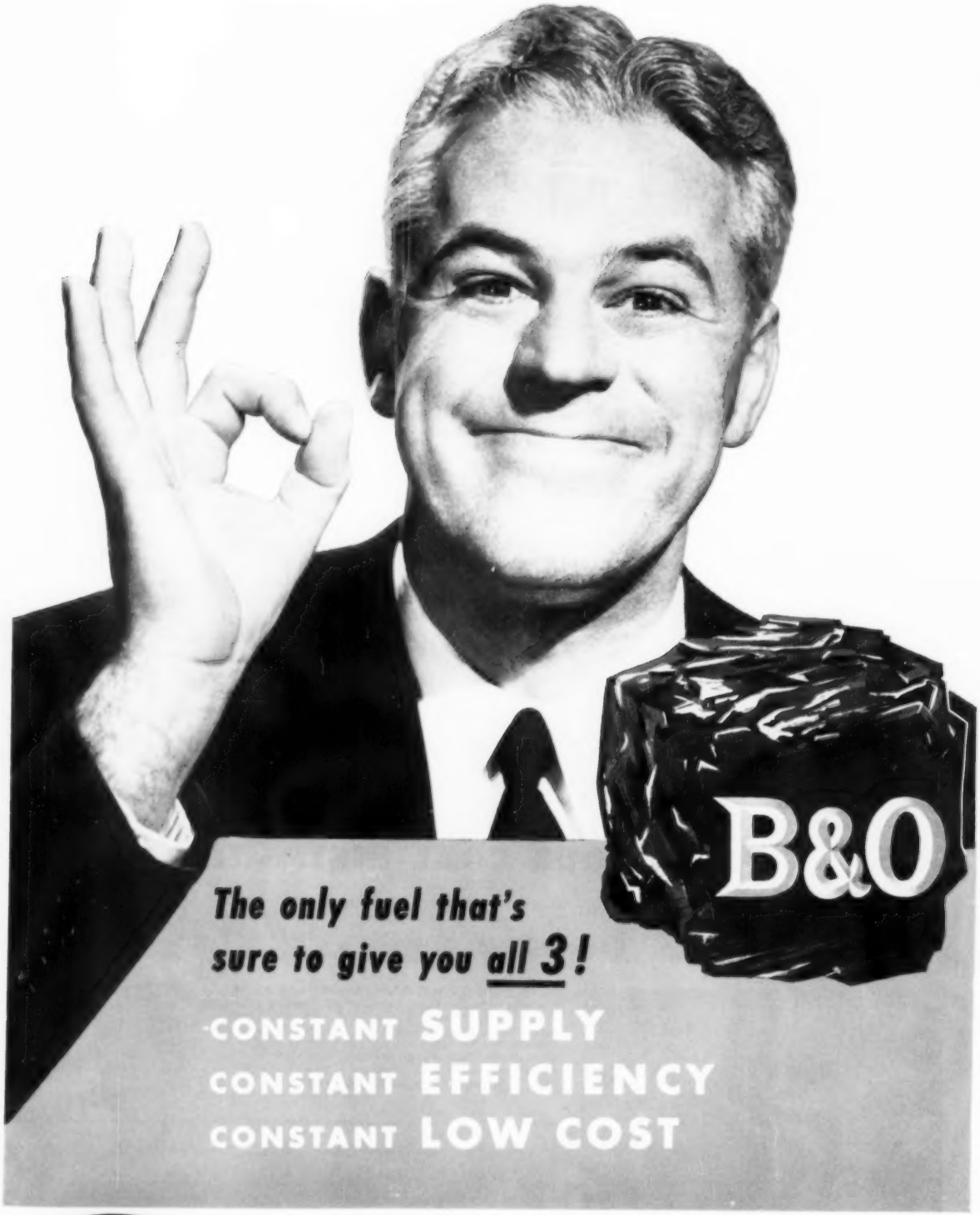

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GRAVER REPORTS ON RESEARCH AND DEVELOPMENT

Here are the Latest Results

...of an intensive program of chemical research and engineering development carried on by Graver Water Conditioning Co. with a twofold purpose:

- to advance the art and science of liquid treatment
- to solve practical problems as they arise on individual jobs

Graver has made, and continues to make, studies of all aspects of equipment design, operating results and process techniques with the view to improving existing methods and developing new ones for the treatment of all types of liquids.

As new achievements are realized through this constant search, they are given practical form and made available for the benefit of the fields served by Graver: *power plant utilities, industrial and municipal water treatment, industrial waste treatment and chemical processing.* The products shown on this page are but a few of the recent developments from Graver's expanding facilities, now the largest in the liquid treatment industry.

OTHER GRAVER ACHIEVEMENTS

Iron and Copper Scavengers • Automation, Instrumentation and Control • Techniques for Prevention of Resin Fouling The Reactivator® • Spherical Ion Exchange Units Rota-Rake® Clarifiers and Thickeners Subfill-less Underdrain Designs • Shericone® Hot Process Sedimentation Units Increase of Ion Exchange Applications • Flotation Units Parabolic Plug Spray Valves • Sub-Surface Washers

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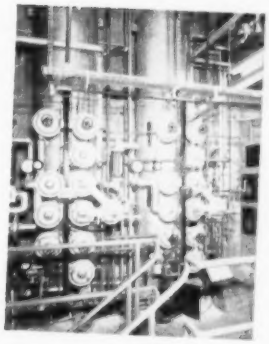
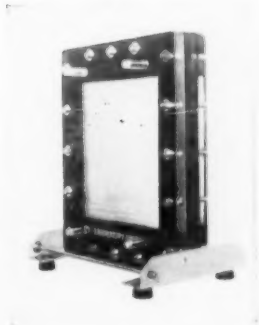
GRAVER WATER CONDITIONING CO.
RESEARCH AND DEVELOPMENT SECTION



REPORT NO: 197

Condensate Scavengers-for power plant utilities. Equipment for internal self-purification of condensate in sub-critical as well as supercritical boiler cycles.

GRAVER WATER CONDITIONING CO.
RESEARCH AND DEVELOPMENT SECTION



REPORT NO: 204

Dialysis Systems and Laboratory Units—for chemical processing and industrial waste treatment. Systems for separation of acid, alkali, neutral salt liquors.

GRAVER WATER CONDITIONING CO.
RESEARCH AND DEVELOPMENT SECTION

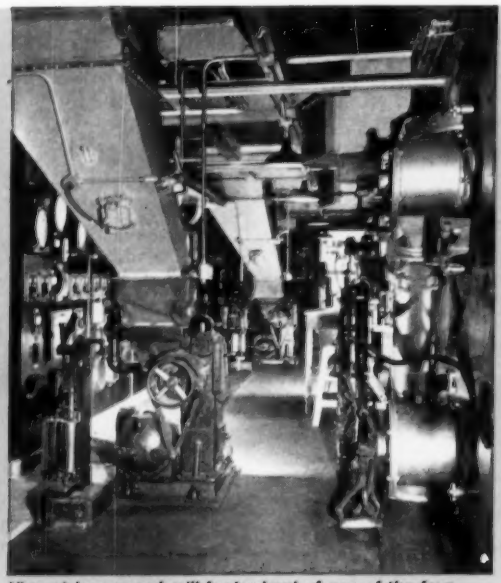
REPORT NO: 193

Non-Corrosive Underdrain — for municipal water treatment. New underdrain for gravity filters weighs much less than other designs and improves backwashing.

GRAVER WATER CONDITIONING CO.
RESEARCH AND DEVELOPMENT SECTION

REPORT NO: 187

Monitoring Systems — for all fields. Systems to check and report malfunction in the operation of demineralization plants, especially of the automatic type.



View at burner and mill-feeder level of one of the four C-E Boilers which serves the Milwaukee plant.

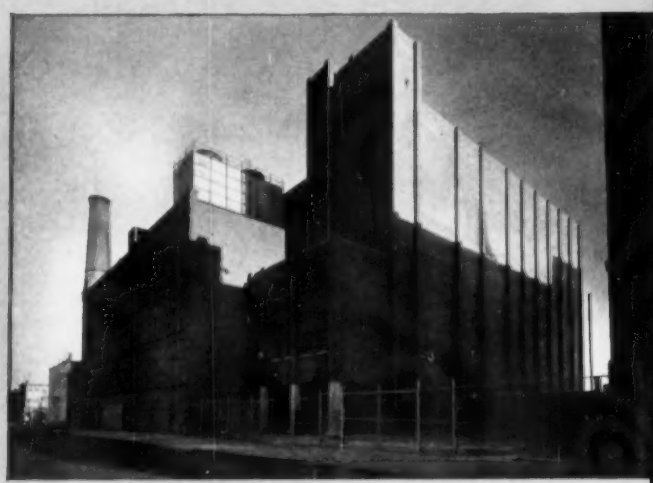
"The Beer That Made Milwaukee Famous"...

Eleven C-E boiler units, ranging from the semi-outdoor, oil-fired package type to the pulverized coal-fired, vertical unit type, provide the steam to make "The Beer That Made Milwaukee Famous."

Since 1946, when the Jos. Schlitz Brewing Company purchased four C-E boilers as part of an expansion and modernization program at Milwaukee, the Company has purchased C-E units for its breweries in Brooklyn, N. Y., Los Angeles, Calif., and Tampa, Fla.

Due to the nature of brewing and bottling operations, load swings are wide and rapid, and boiler response must be both unfailing and prompt. How well C-E boilers have met this challenge is evidenced by the repeat order record—a record made even more impressive by the fact that the Jos. Schlitz Brewing Company has obtained consistently high performance with not just one type of C-E boiler — but with three.

When you need a reliable and efficient source of steam — remember that the Schlitz slogan "Move Up to Quality" applies to boilers as well as beer.



Two oil-fired C-E boilers, Type VU-10, supply 60,000 lb. of steam per hr. for process purposes at the Schlitz brewery in Brooklyn, N. Y.

COMBUSTION

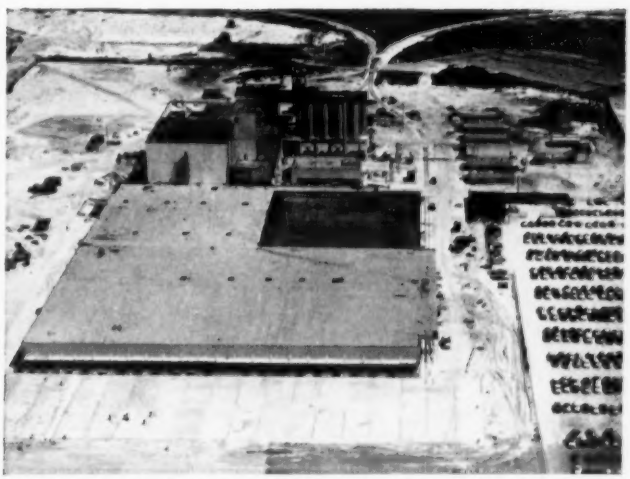
Combustion Engineering Building,

ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT; NUCLEAR REACTORS;

The Schlitz "headquarters" brewery at Milwaukee uses 4 pulverized coal-fired C-E boilers, Type VU, each with a capacity of 60,000 lb. per hr.

is brewed with C-E STEAM

This 20-million dollar showplace is the Schlitz brewery in Los Angeles, California, which uses 3 C-E boilers, Type VU-10. Fired with natural gas and oil, they generate 90,000 lb. of steam per hr.



At its Tampa, Florida, brewery, Schlitz uses 2 semi-outdoor C-E Package boilers, Type VP. They provide 72,000 lb. of steam per hr.

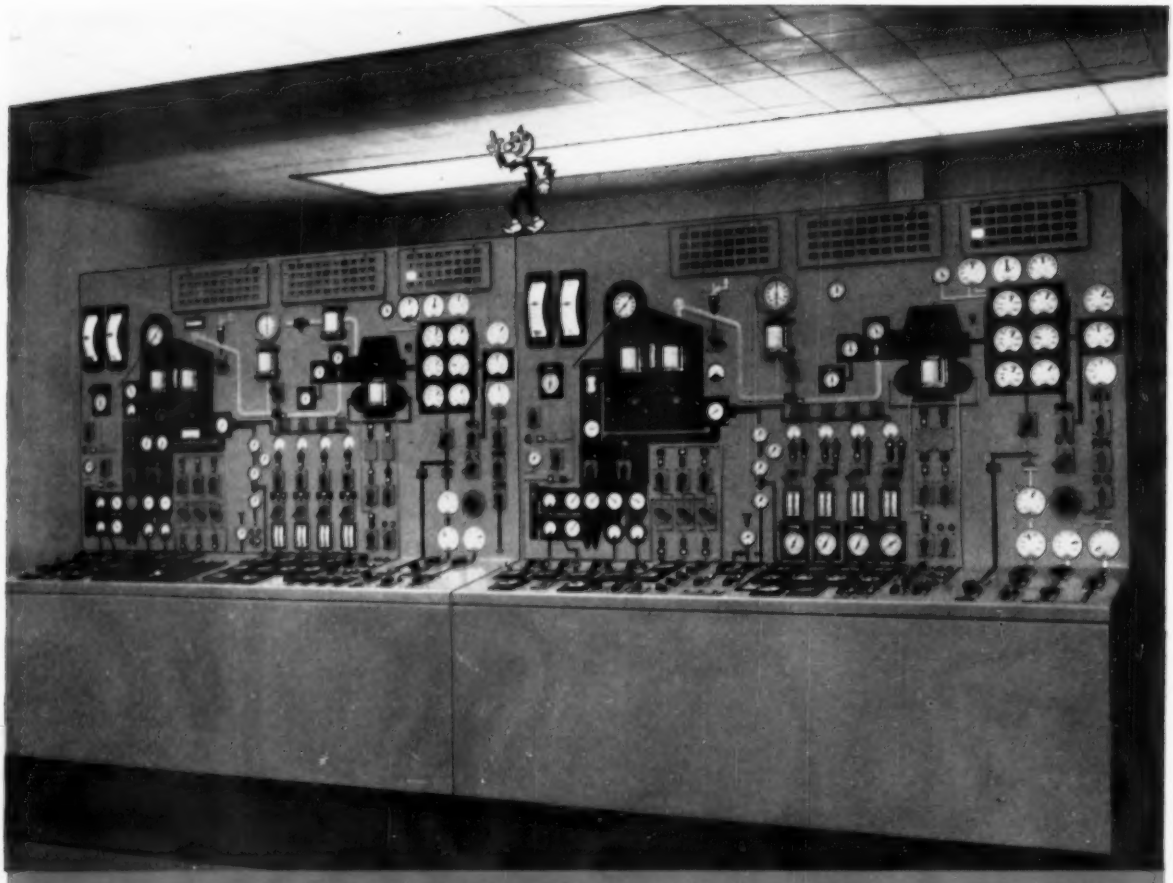
ENGINEERING

C-E

C-196

200 Madison Avenue, New York 16, N. Y.

PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS; SOIL PIPE



The Louis V. Sutton Plant uses centralized control for each unit. All instruments are of the miniature type, permitting a reduction in size of panel. Engineers and constructors: Ebasco Services, Incorporated.

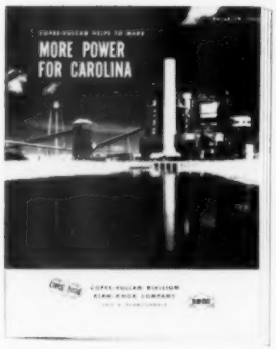
It's Copes-Vulcan Combustion Control at Louis V. Sutton Plant!

Units 1 and 2 in the Louis V. Sutton Steam-Electric Generating Plant of Carolina Power & Light Company are equipped with Copes-Vulcan combustion control. This modern system features simplicity of circuit design, with independent control loops on air flow, fuel loading and furnace draft. Interconnection of the control loops is eliminated because of the speedy response of each of the components.

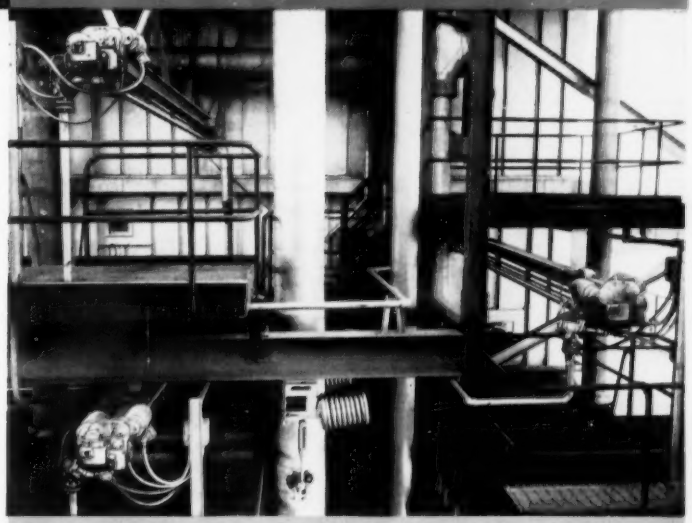
Station and controller design facilitates remote switching from automatic to manual, or manual to automatic. Variations in circuit design would provide for shortening tubing runs between controllers and drive units, valves or other controlling devices, should transmission lines become excessively long.

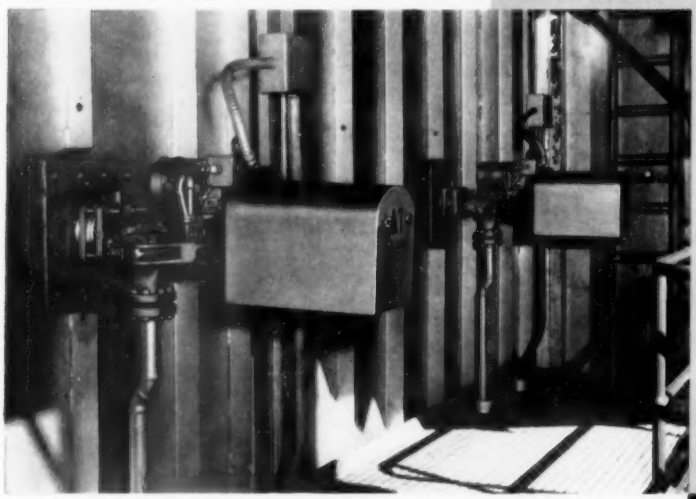
Modern Copes-Vulcan combustion control systems offer many advantages that will help you reduce production costs. In addition, from this one dependable source, you can get a fully integrated system including feed water control, boiler feed pump recirculation control, steam temperature control and automatic soot blowing. Your Copes-Vulcan representative has the ideas, information and experience to help you choose the system best suited to your needs.

C-V NEWS NOTES



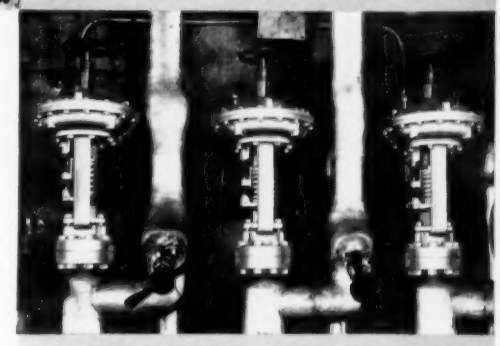
For a complete description of the Sutton Plant control system, see your Copes-Vulcan representative, or write the factory for Bulletin 1032.





Vulcan long retractable soot blowers are installed on Units 1 and 2. Both soot blowing systems feature automatic-sequential control.

Copes-Vulcan RW-2E wall de-slaggers on Unit 2 have dual-motor electric drive. One motor extends and retracts the lance, the other rotates the nozzle.



Copes-Vulcan boiler feed pump recirculation valves on Units 1 and 2 open automatically when water flow falls below a pre-determined minimum. When flow reaches a predetermined maximum controller closes the valve.

COPES VULCAN

BLAW-KNOX

COPES-VULCAN DIVISION

BLAW-KNOX COMPANY

ERIE 4, PENNSYLVANIA

For economical "solid pour" construction

... strong for

Below, Solid-Pour Steam Main Conduit where additional drainage was needed

2" X 12" PLANK TIGHT SHEETING
NOTE: NAIL 1" X 2" SLATS OVER ANY OPEN VERTICAL JOINTS OR CRACKS IN TIGHT SHEETING DURING CONSTRUCTION
THIS PORTION OF TIGHT SHEETING TO BE REMOVED
12" STEAM MAIN
12"
SOLID POUR CONCRETE
3" THERMOBESTOS INSULATION
GROUND-WATER LEVEL
2'-0" ±
PEA, PEBBLE AND SAND FILL
4" SLIP SEAL VIT SEWER PIPE
4" CROCK UNDER DRAIN
CONCRETE MUD MAT

leading Midwest public utility uses

durable Thermobestos Insulation underground steam lines

Johns-Manville Thermobestos provides its own support in wet concrete . . . after drying, retains its original conductivity—lowest of all the calcium silicates

A GIANT public utility in the Midwest has discovered an ingenious way to use Thermobestos* underground —it's known as the "solid pour" method, and it's illustrated below.

Those who've tried "solid pour" construction will tell you that you can't match its economy—and material savings are truly substantial! There's no pouring of separate bottom, no building and placing of forms, no envelope! And Johns-Manville Thermobestos pipe insulation lets you use this economical method just about anywhere.

Thanks to its high compressive strength, Thermobestos needs no pipe supports, provides its own "no-cost" buffer between pipe and concrete. Thermobestos and "solid pour" methods have been successfully used in areas where drainage problems exist and flooding is a possibility. For even though it should become saturated with water, Thermobestos regains its original low conductivity as soon as it dries out.

Ever since its introduction, Thermobestos has been widely acclaimed throughout the power-generation and process industries for insulating indoor and outdoor pipelines to 1200F. Its *k* factor is the lowest of all insulations in general use for these services.

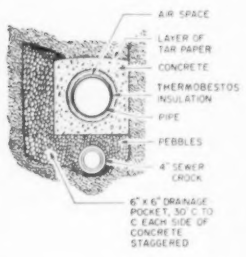
Thermobestos also offers top strength and rigidity; withstands crushing, easily resists unusual service abuse. Yet with all its strength, it is lightweight for easy handling and fast application.

A hydrous calcium silicate that's molded to size for proper fit, Thermobestos is quick, easy to apply . . . its strength makes it particularly adaptable to time-saving prefabrication of fittings and bends. Furnished in large sections, Thermobestos reduces the number of joints needed . . . comes in a complete selection of pipe insulation sizes up to 30" O.D. Also available in 6" x 36" and 12" x 36" blocks in a full range of thicknesses.

Let us send you a copy of the informative Thermobestos booklet, IN169A. Write Johns-Manville, Box 14, New York 16, N.Y. In Canada, Port Credit, Ontario.

JOHNS-MANVILLE

JOHNS-MANVILLE JM PRODUCTS

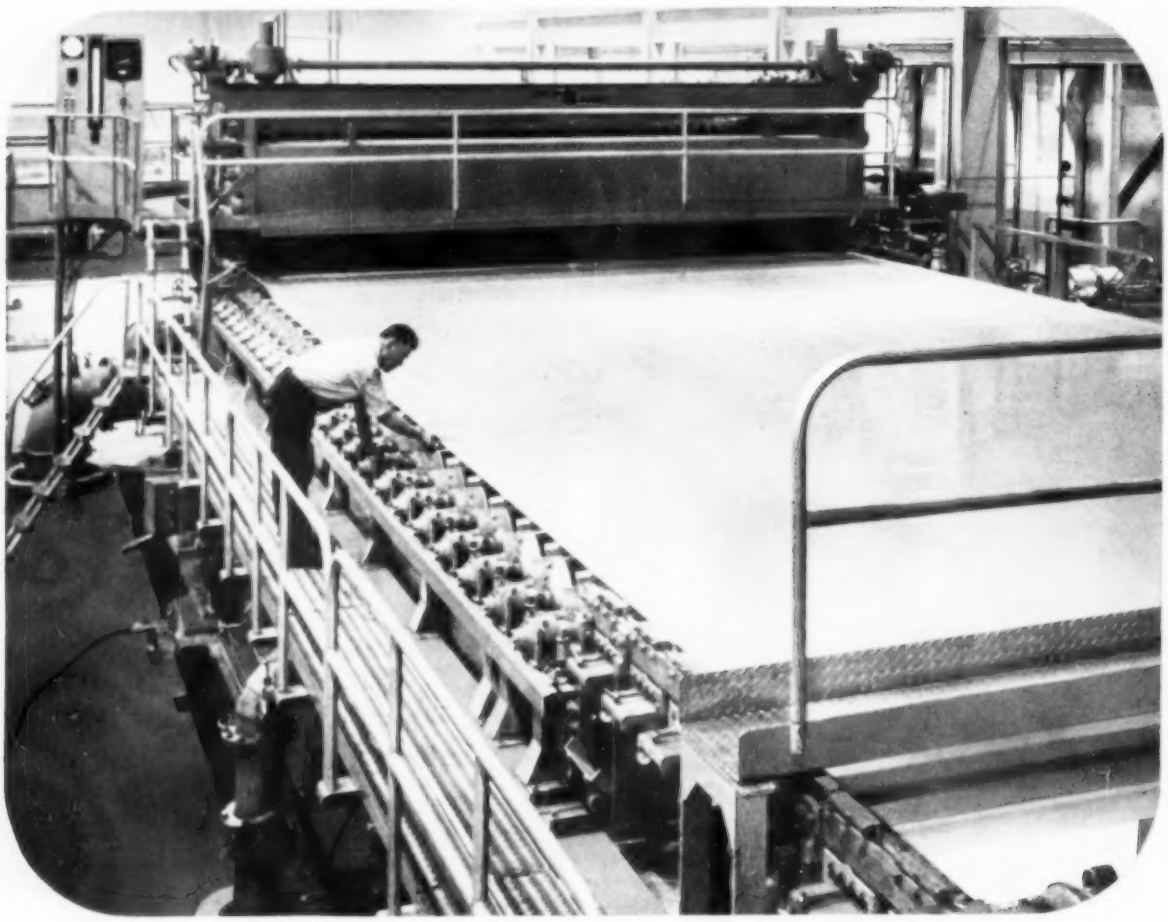


Above, Solid-Pour Steam Main Conduit

Ready for "solid pour." Thermobestos insulation is shown in position with waterproof jacketing partly installed (see diagram for trenching detail).

Easily withstands weight of poured concrete. Here in the same trench Thermobestos is shown with concrete poured solidly around it.

ION EXCHANGE RESINS condition boiler feed



Wet end of Fourdrinier paper machine at a Minnesota and Ontario Paper Company Mill

MINNESOTA and ONTARIO PAPER COMPANY needs water of low mineral content for power generation and processing . . . uses AMBERLITE Ion Exchange Resins

It takes a lot of water to run a paper mill, not only as an actual ingredient in paper making, but also for the steam necessary for power generation and for cooling paper machine condensate.

At Minnesota and Ontario Paper Company in International Falls, Minnesota, the feed water to the boiler—rated at 240,000 lbs. per hour, 1290 psig.—must be deionized. This is accomplished by passing the feed water through 1) two parallel beds of AMBERLITE IR-120, a strongly acidic cation exchange resin operating in the hydrogen cycle, 2) a vacuum deaerator, 3) and through two parallel beds of AMBERLITE IRA-400, a strongly basic anion exchange resin. The water has a conductivity of only 1.5 to 3 micromhos, with a silica content of less than .015 ppm. Deionized water requirements vary from 100 to 300 gallons per minute.

Perhaps your organization, too, has a water conditioning problem. If so, your engineering company specializing in water conditioning is qualified by experience to recommend how AMBERLITE resins can best serve your particular needs. For detailed information about AMBERLITE resins, write for the booklet, "If You Use Water."

AMBERLITE is a trade-mark, Reg. U.S. Pat. Off. and in principal foreign countries.

Chemicals for Industry

ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.

Representatives in principal foreign countries

72 tons of *FLY ASH* collected a day!

GREEN'S AERODYNE HELPS SOLVE CONSOLIDATED EDISON'S FLY ASH PROBLEM

Installation of Aerodyne Units at Consolidated Edison's Hell Gate Electric Generating Station.

Green makes this AERODYNE mechanical dust collector, to collect fly ash and other dusts. Does this Green AERODYNE really work?

Well, let's quote a few words from Mr. J. J. Grob, Chief Performance Engineer, Mechanical Engineering Department, Consolidated Edison Company of New York, Inc.

QUOTE 1
Why used . . . . . "At Hell Gate Station two Aerodyne mechanical collectors were installed in the uptake flues of boilers No. 11 and 12 for removing the bulk of fly ash leaving the furnaces."

QUOTE 2
72 tons of fly ash per day . . . . . "The furnaces are slag tap and, of that ash which would otherwise be expelled to the electrostatic precipitators before entering the stack, the Aerodyne units, based on careful tests, remove approximately 72 tons of fly ash per day."

QUOTE 3
Satisfactory . . . . . "The operation of the Aerodyne mechanical collectors has been satisfactory and the life of the cones has greatly exceeded expectations."

We repeat, in all modesty — Green can help you solve FLY ASH and DUST collection problems.

Why not write and ask us?

Green

THE GREEN FUEL ECONOMIZER CO., INC. **BEACON 3, NEW YORK**

Hagan Dust Collector Tube shows

no erosion

after collecting 160 tons of slag dust

The collector tube shown here was cut from a 184 tube Hagan Aerostatic Dust Collector installed on a blast furnace slag dryer at the Neville Island Plant of the Pittsburgh Coke and Chemical Company. The collector has been in operation for more than two years, collecting slag dust at the rate of 23,400 tons per year.

The dust loading from the slag dryer is about 25 grains per cu. ft., almost ten times the loading from the average coal fired boiler and many times more abrasive. During its two years of operation, the Hagan collector has been consistently operating at 93% efficiency, despite the extremely fine dust it has been handling.

This Hagan collector not only enables Pittsburgh Coke and Chemical to comply with rigid air pollution regulations, but recovers valuable material as well. Add the economies that result from the sharp reduction in maintenance costs, plus the fact that the Hagan Collector is easily installed, and you have a cost picture that offers both short range and long term economies.

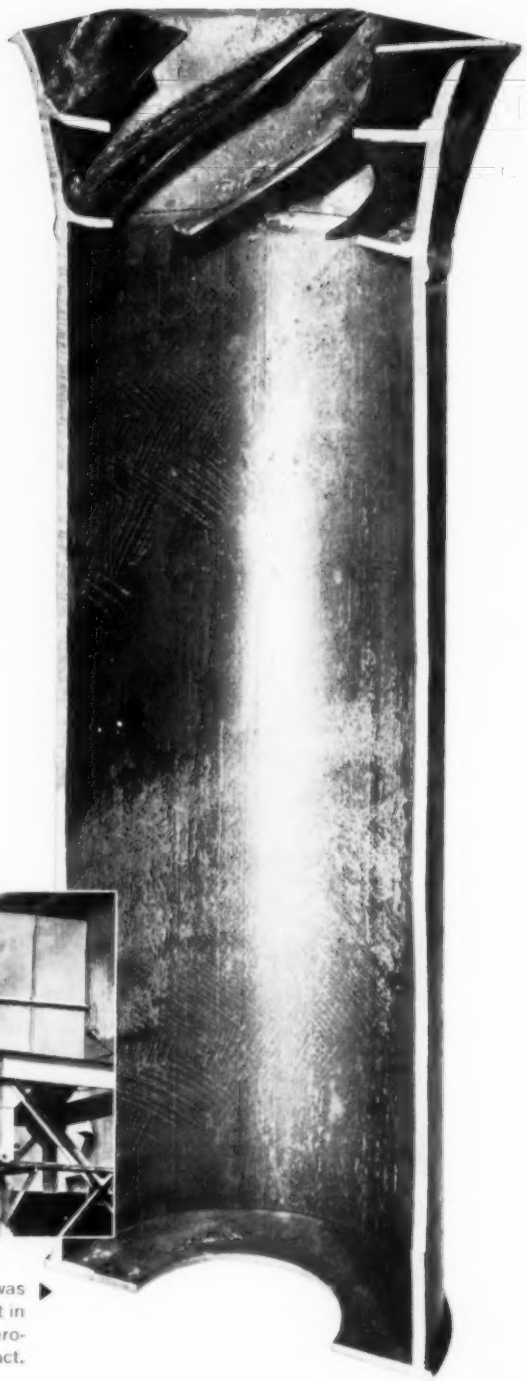
Get the full facts on how the exclusive Hagan principle of Selective Particle Acceleration can save you money. Write for Bulletin MSP-124 A.

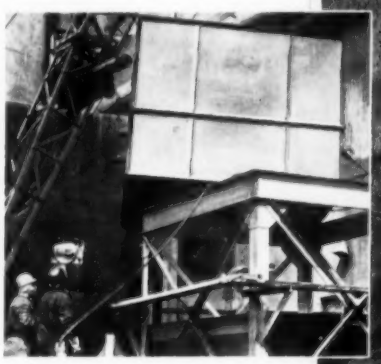
HAGAN CHEMICALS & CONTROLS, INC.

DIVISIONS: CALGON COMPANY, HALL LABORATORIES

HAGAN BUILDING, PITTSBURGH 30, PA.

In Canada: Hagan Corporation (Canada) Limited, Toronto
European Division: Via Flumendosa No. 13, Milano, Italy





Installation of a Hagan Dust Collector. The fast installation possible with the fully pre-assembled Hagan unit is a money and time saver.

More than 160 tons of highly abrasive slag dust was collected by this tube over a period of 15 months. Cut in half for inspection, the tube shows no evidence of erosion; in fact, most of the mill scale still remains intact.

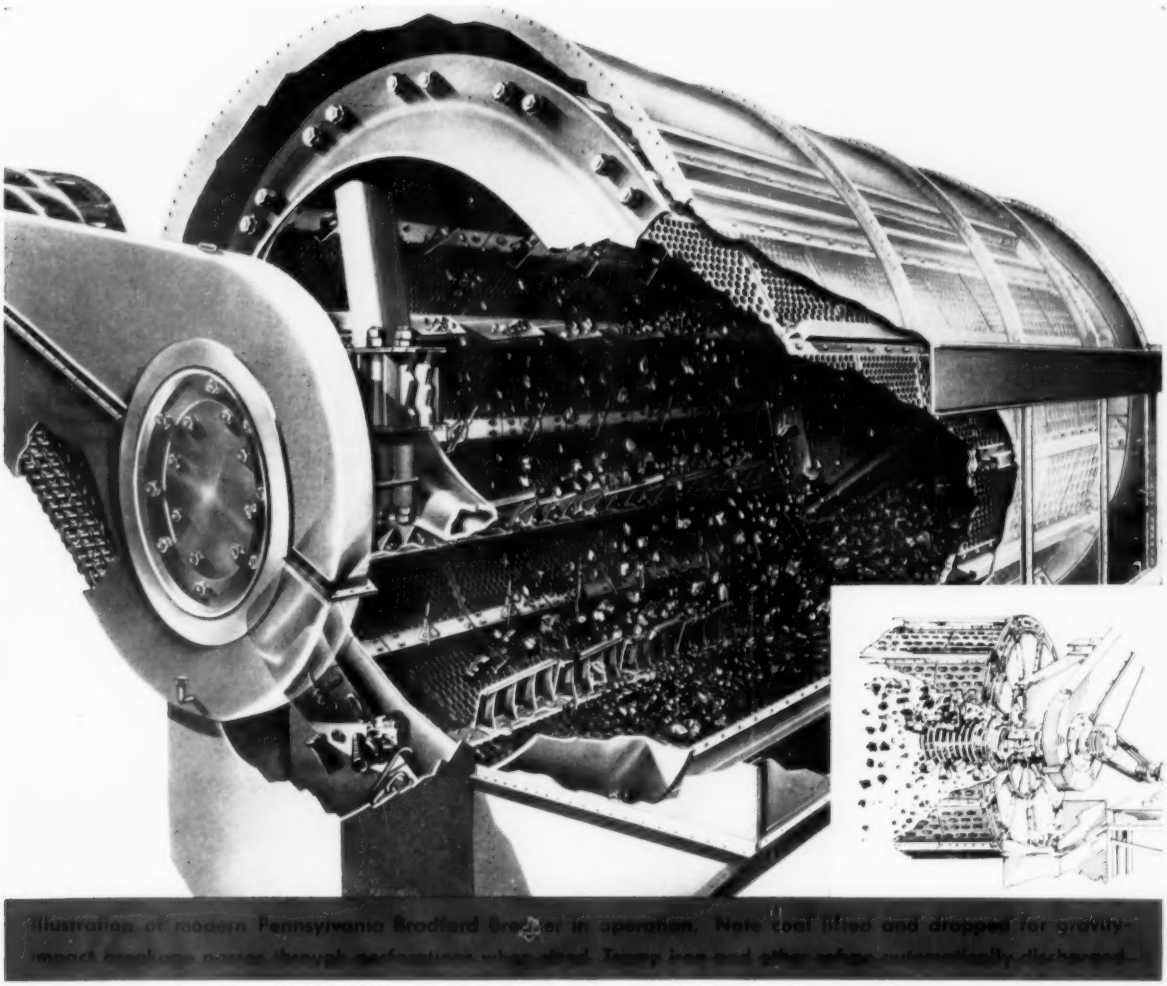


Illustration of modern Pennsylvania Bradford Breaker in operation. Note coal lifted and dropped for gravity-impact cracking across through perforations when closed. Tramp iron and other refuse automatically discharged.

It cleans coal as it crushes AT NO EXTRA COST

The Pennsylvania Bradford Breaker has no peer in the preparation of run-of-mine coals. This is borne out by the fact that Pennsylvania Bradfords condition over 38 million tons of coal annually in power plants all over the world. This has been going on for many, many years and it's your assurance of dependability. For the preparation of extra hard coals the Pennsylvania Bradford Hammermill is usually preferred. This crusher is a Bradford Breaker with a swing hammer rotor placed at the discharge end that reduces all oversize so it can pass thru the cylinder perforations, thus eliminating any waste of oversize that otherwise might pass out the discharge end.

For complete information on these Breakers, ask for Bulletin 3009. Pennsylvania Crusher Division, Bath Iron Works Corporation, West Chester, Pennsylvania.

Penn
CRUSHER

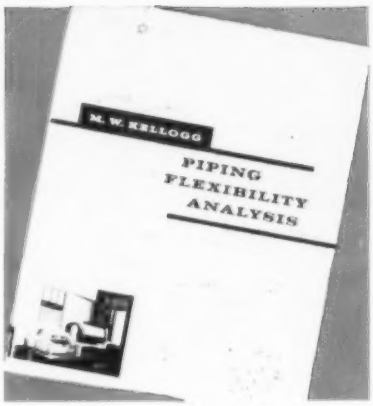
KELLOGG'S PIPE SHOP FABRICATION KEEPS PACE

This complex header for the hot reheat line, here being finished at M. W. Kellogg's Jersey City shops, is an important part of the power piping for Alabama Power Company's Unit No. 3 at Barry, Alabama. This modern steam-electric plant addition in Mobile County is designed for operation at 2000 psi and 1000°F initial temperature; 1000°F reheat. The turbine will supply 225,000 KW.

All power piping for the unit is being fabricated and erected by Kellogg, who will also furnish and install all hangers, guides, anchors, supports, and similar equipment. K-Weld®, Kellogg's unique, inert gas-shielded arc welding technique, is being used on the main steam line and hot reheat lines, and was used in fabricating the header shown above.

Dimensions of the critical steam lines being fabricated of $1\frac{1}{4}$ Cr., $\frac{1}{2}$ Moly. in Kellogg's Jersey City shops are: *Main Steam*—17.5" O.D. x 2.25" minimum wall, and 12.75" O.D. x 1.6875" minimum wall; *Hot Reheat*—26" O.D. x 1.24" minimum wall, and 16" O.D. x 0.8025" minimum wall.

Kellogg welcomes the opportunity to discuss its complete power piping design, fabrication, and erection facilities with consulting engineers, engineers of power generating companies, and manufacturers of boilers, turbines, and allied equipment.



This new 8-page booklet, fully describing Kellogg's electronic computer method of making piping flexibility analysis, has just been published. Write for a copy.

Fabricated Products Sales Division

THE M. W. KELLOGG COMPANY, 711 THIRD AVENUE, NEW YORK 17, N. Y.

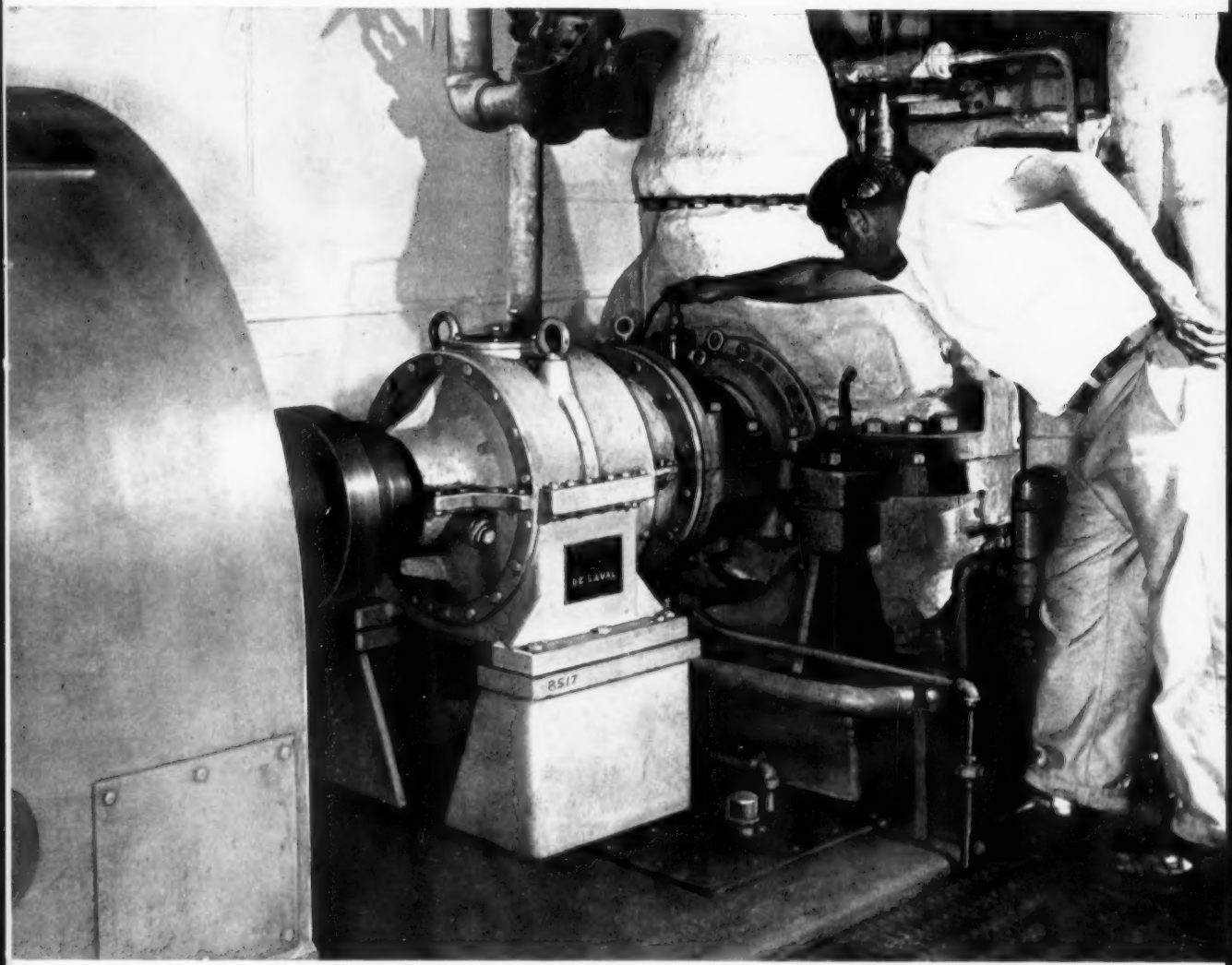
A SUBSIDIARY OF PULLMAN INCORPORATED

The Canadian Kellogg Co., Ltd., Toronto • Kellogg International Corp., London • Kellogg Pan American Corp., New York
Société Kellogg, Paris • Companhia Kellogg Brasileira, Rio de Janeiro • Compania Kellogg de Venezuela, Caracas

POWER PIPING—THE VITAL LINK

® *Registered trademark of The M. W. Kellogg Company*

Creative Engineering by DE LAVAL



De Laval-Stoeckicht Gear at Homasote Co., Trenton, N. J.

2800 Horsepower in a 22" package!

That compact "package" you see in the center of the picture above is a De Laval-Stoeckicht Planetary Gear. Developed by W. G. Stoeckicht in Germany, this gear has been proved in hundreds of European installations. It is capable of transmitting 2800 horsepower from the steam turbine at the right to the generator at the left. It weighs only 900 pounds. A conventional gear for this service would weigh 4000 pounds. And the De Laval-Stoeckicht gear takes up less than half the space of a conventional gear. This is another example of how De Laval *creative engineering* plus precision manufacturing and highest quality control assure lasting customer satisfaction.

DL 449

DE LAVAL *Steam Turbine Company*

886 Nottingham Way, Trenton 2, New Jersey

No matter the size of the job, critical piping is work only for specialists. So many top power and processing plants know the lasting satisfaction to be had from using Mitchell direct from start to finish...for prefabricating and erecting your new high-temperature, high-pressure piping...ask us in.

W. K. MITCHELL & CO., INC.

Philadelphia 46, Pa.

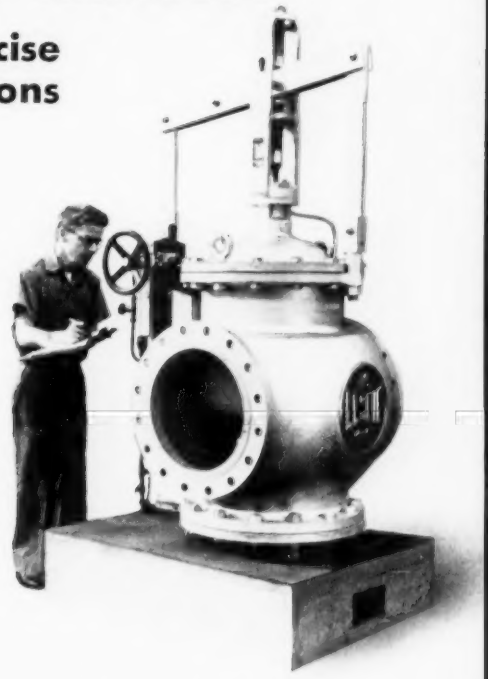
WESTPORT JOINT
(PATENTED)

MITCHELL *PIPING*
SINCE 1899

PIPING FABRICATORS AND CONTRACTORS

LESLIE - *lifetime control valves . . .*

A complete line for precise power applications



Leslie Co. offers a wide range of single seated valves in sizes ½" to 16" and double seated control valves. In addition, there are many new standard valves designed specifically for power industry applications in both sub-critical and super-critical power generating stations. Valves are available with these power service features:

- **Exclusive Leslie seat protections eliminate erosion problems in high-pressure drop throttling services.**
- **New Leslie "cage" construction permits replacement of inner valves, seats and guides without removing valve body from the line. Down-time for replacement or inspection is cut to a minimum less than 20 minutes.**
- **Control valves in extremely severe high-pressure drop service have infinite rangeability.**
- **Stellite faced and solid stellite inner valves and seating surfaces for maximum erosion resistance.**

Leslie control valves are designed to handle hot and flashing condensate . . . temperatures to 1150°F per ASA rating. They are providing reliable service under extremely severe operating conditions in a variety of central station applications such as:

- **Condensate drains from feedwater heaters**
- **Boiler feed pump recirculation**
- **Desuperheater spray water control**
- **Turbine lead drain remote manual start-up control**

You may choose from a variety of sizes and diaphragm actuators to accommodate almost any operating air supply up to 100 psi. In addition, electro-mechanical, pneumatic cylinder and electro-hydraulic actuators can be supplied.

For specific engineering data, write today for data sheets illustrating the cage trim construction and other Leslie features.

TRADE LESLIE MARK

REGULATORS and CONTROLLERS

LESLIE CO., 218 Leslie Bldg., Lyndhurst, New Jersey

THE BAYER CO.

MANUFACTURERS OF BAYER SOOT BLOWERS

For Highest First and Final Value

. . . BUY BAYER!

BAYER

Balanced Valve

SOOT CLEANER

Bayer's single-chain design compels perfect in-step operation of valve and element. Operation is positive, definite, assuring a full flow of steam for efficient cleaning.

When the operator pulls chain, the cam-actuated, quick-action balanced valve is opened. By continued pulling of the chain, worm drive slowly rotates element over cleaning arc. When element reaches end of cleaning arc, valve automatically closes.

Minimum steam consumption—low maintenance. Every detail is engineered, built for long life, efficient performance at high temperatures and high pressures.

More than 35,000 boilers are Bayer equipped. More than 50 years' successful, specialized experience assures you investment economies in Bayer equipment.

QUALIFIED LOCAL ENGINEERING SERVICE—Your Bayer representative is an experienced engineer, well qualified to take care of any service needs in connection with Bayer Soot Cleaners. He is available when you call upon him and will gladly render any service required.

All These Mechanical and Operating Advantages are available in

The BAYER *Balanced Valve* SOOT CLEANER

1. **Sound engineering, workmanship, and materials of the best.**
2. **An organization of over 50 years' experience, capable and willing to render service at all times.**

SINGLE CHAIN: Valve and element controlled by a single chain.

VALVE BODY: Rugged construction, built to last. Short and ample steam passage giving very small pressure drop.

ORIFICE PLATE VALVE: For high pressure service, each head may be controlled by an orifice plate valve through which pressure is adjusted for each individual element.

STUFFING BOX: Due to maintenance of perfect alignment on swivel tube, packing needs little attention. Stuffing box is in full view, readily accessible.

AIR SEAL: Has machined surface on wall sleeve and spring-held floating seal to prevent air in-leakage.

HEAD BEARINGS: There are two main bearings, an outboard and an inboard bearing for the swivel tube to maintain alignment.

THRUST BEARING: Ring type thrust bearing takes the load.

VACUUM BREAKERS: Two vacuum breaker air valves, or one valve and a signal whistle above each valve, to prevent suction of boiler gases into valve and piping.

ELEMENT OPERATION: With the Bayer element operation, balanced valve is opened just as element rotates, giving FULL pressure over entire cleaning arc. Full steam pressure insures thorough cleaning. Balanced valve saves wear of valve parts. With any type of poppet valve, this is important . . . ask any operator.

BLOWING ARC: Valve cams automatically regulate cleaning arc.

REDUCTION GEARS: 24 to 1 gear ratio gives slow rotation for good cleaning.

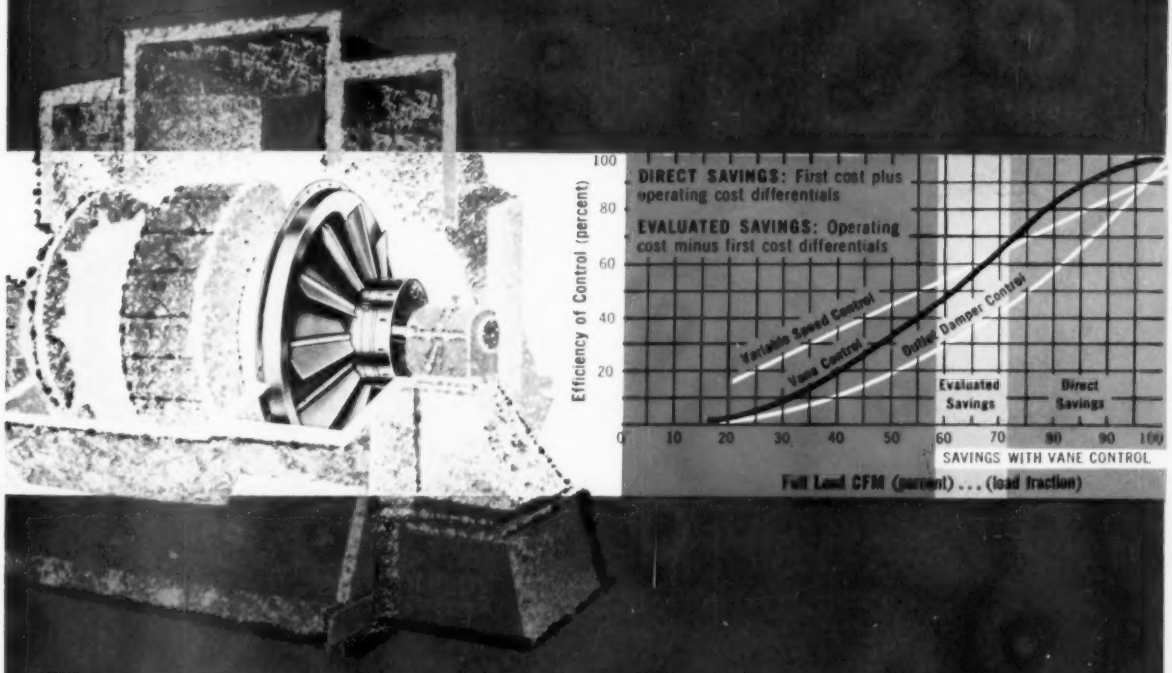
FLANGED PIPE CONNECTION: Operating head is connected to supply pipe by flanges and through bolts, or high tensile studs and nuts.

THE BAYER CO.

St. Louis, Mo.

DON'T SPEND $12,000 ON A $4,000 JOB

and still lose money on operating costs!



Westinghouse Inlet Vane Air Spin Control
is the best way to regulate forced and induced draft fan volume with constant speed motors

* Lower First Cost * Lower Operating Costs * High Efficiency

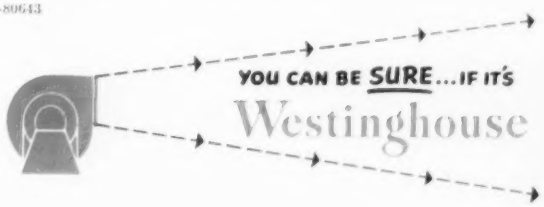
Specify this simple, reliable and mechanically foolproof regulator of fan output for your combustion control. Action is smooth. Response to exact pressure and volume requirements is instantaneous, adjustment precise.

Westinghouse Vane Control can be used on Forced and Induced Draft! Available in distinct designs for clean air forced-draft and coal-fired induced-draft applications.

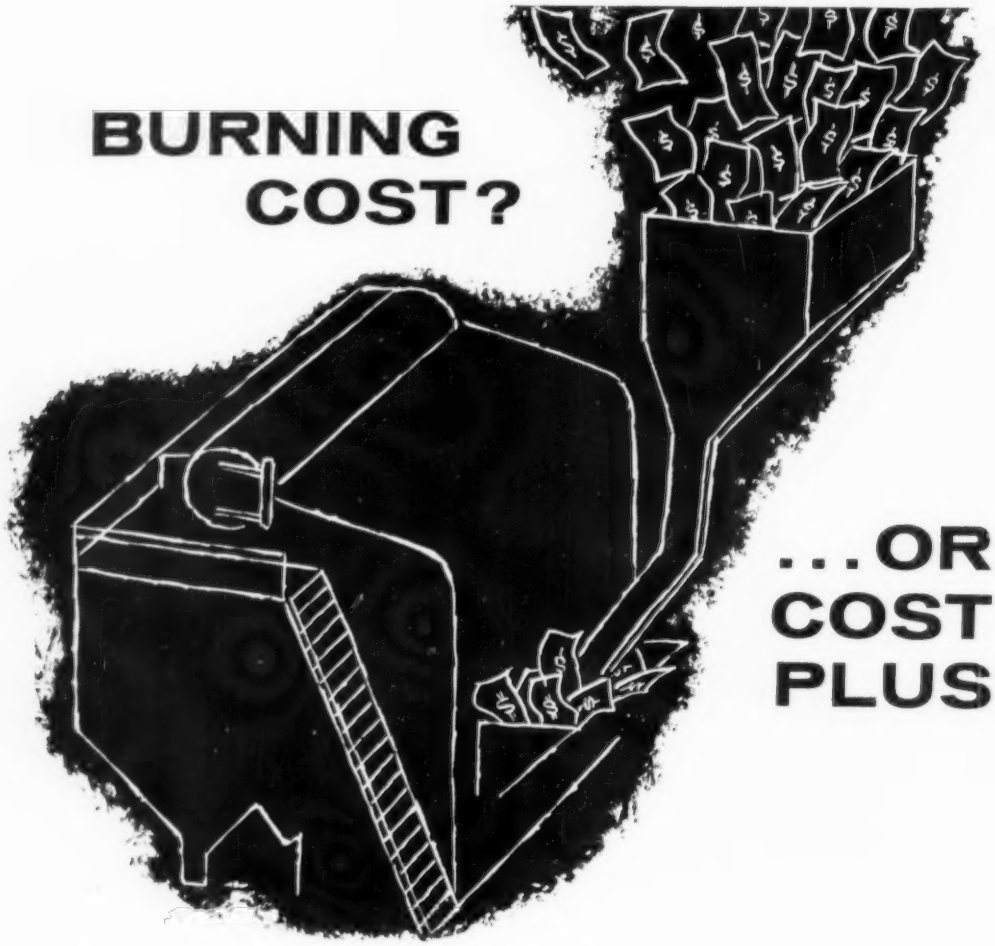
Hundreds of power plants are benefiting from the economy and effectiveness of Westinghouse Inlet Vane Control on Forced and Induced Draft Fans.

Call your local Sturtevant Division Sales Engineer today, or write Westinghouse Electric Corporation, Dept. B-3, Hyde Park, Boston 36, Massachusetts.

J-80643



BURNING COST?



...OR COST PLUS?

If your boiler, like most, annually consumes its first cost in fuel . . . even a fractional per cent efficiency drop can mean substantial dollar loss.

Holding a boiler to design-engineered efficiency starts with highest standards of operation—continues when these are matched by equally high standards of maintenance.

Apexior Number 1 internal protective coating establishes for the lifetime of any boiler, at pennies-per-square-foot cost, the ultimate in sound, clean surfaces. Apexior-coated tube and drum steel, free from heat-transfer barriers, puts b.t.u.'s to work more efficiently over longer in-service time—thus helps a boiler meet easily . . . or even better . . . designer-operator expectations for economical perfomance.

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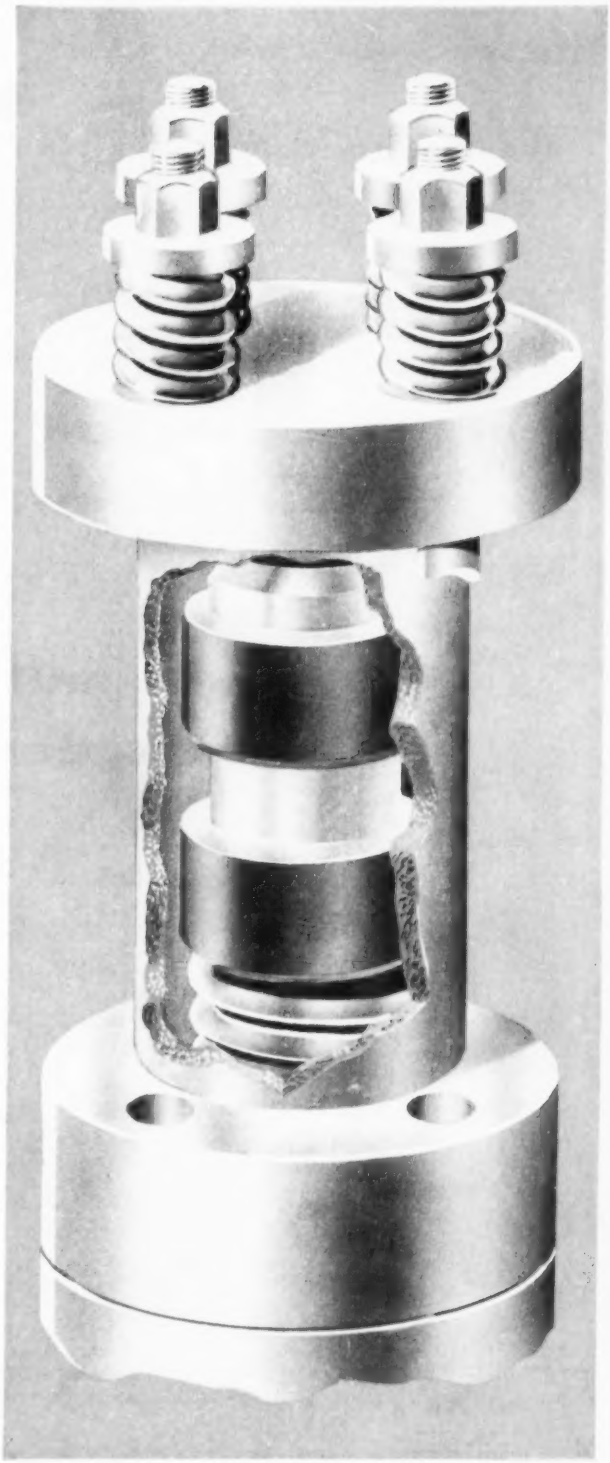

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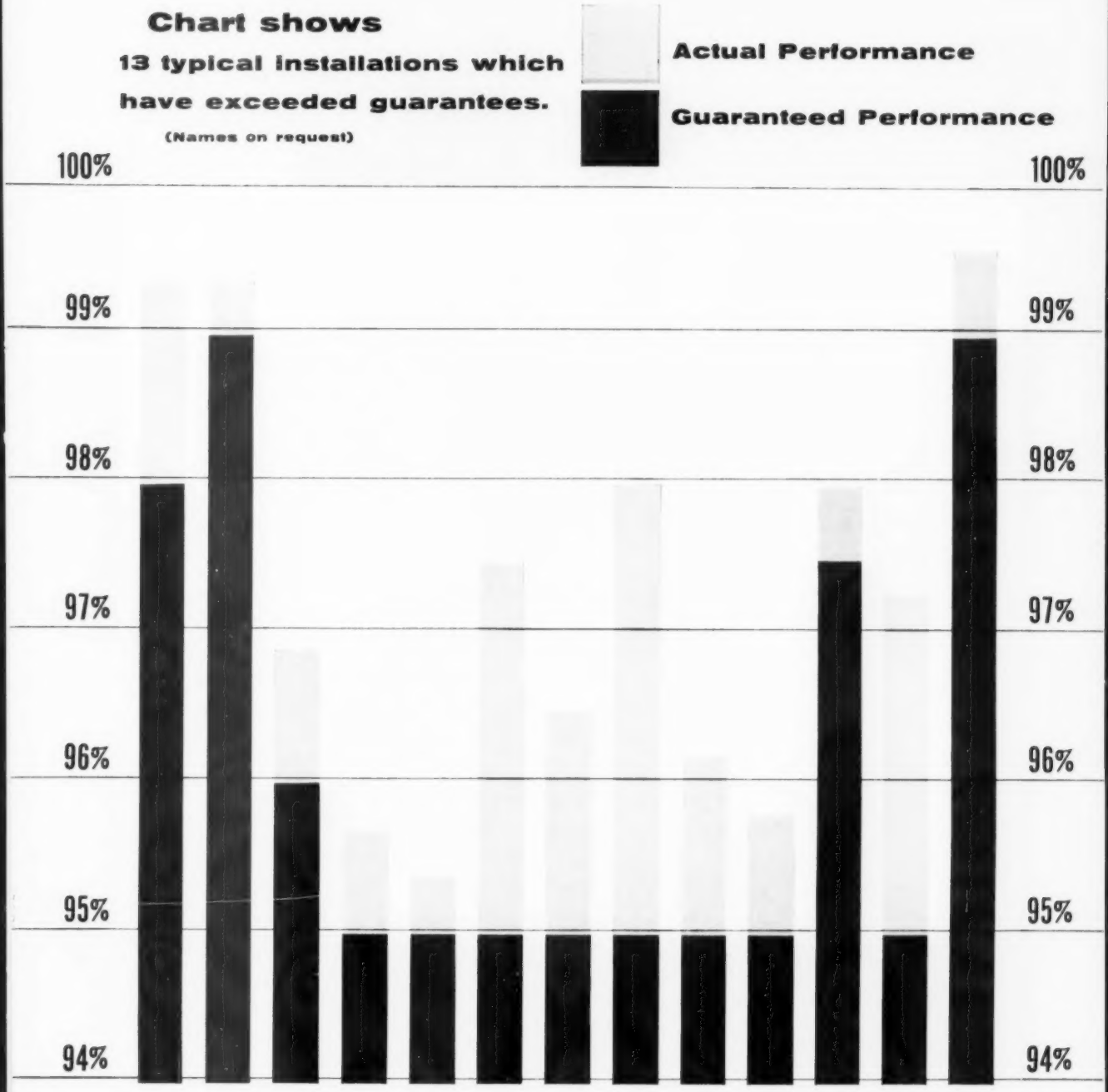
RESEARCH

Chart shows

13 typical installations which have exceeded guarantees.

(Names on request)



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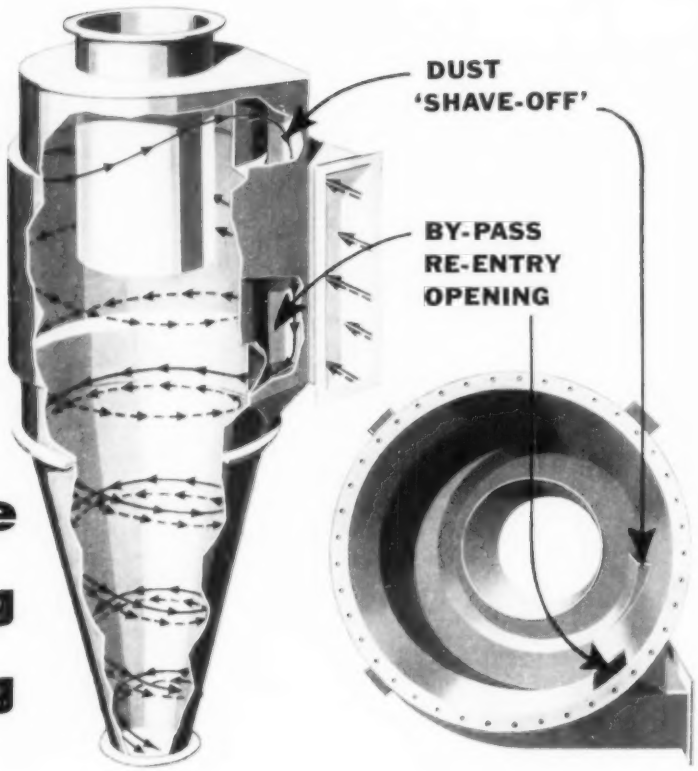

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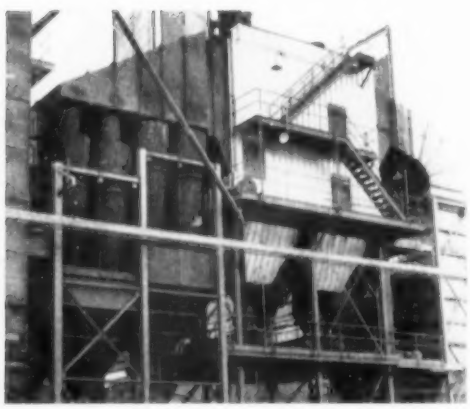

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COMBUSTION

Editorial

Education by Fits and Starts

The way we in America face up to our national problems would convince an outsider our modus operandi is by fits and starts. For example, as evidenced by our Congressional investigations, we seem to let our ills become deep-seated before we become aware of them and take hurried steps to curb or correct them. Now we are concerned on a national scale with the shortcomings of our educational system. We hope the clamor won't lead to indiscriminate tinkering and experimenting.

At the winter general meeting of the American Institute of Electrical Engineers the topics of education, scientific developments and research philosophies came in for considerable attention from some of the top minds in the country. Dr. James R. Killian, Jr., chairman of the MIT Corporation and also chairman of President Eisenhower's Scientific Advisory Committee, underlined the gravity of the situation with this statement: "Survival depends upon the vigor and effectiveness of our science and technology." This statement needs no further emphasis. We all agree.

Dr. Killian was joined by Dr. Mervin J. Kelly, chairman of the board, Bell Telephone Laboratories, in censuring the general public for the major responsibility for sapping the vigor and effectiveness of our technology. It was the confusion of the general public between what is science and what is engineering in Killian's opinion that led to this past fall's significant drop in students entering engineering schools. Kelly, in the same vein, felt the public's influence upon secondary schools had created a lackadaisical situation and he expressed this undermining in these words: "Neither in its finding of the talented and arousing their interest nor in the development of the talent is our secondary school system performing the service to our society that the challenge it faces requires."

Here, we believe, is the crux of the problem uncovering talented youth at the start of their high school years when we in this country first begin to specialize and to begin pointing for a niche in life. It is to the national interest that this weakness in our educational system be met head on. The decision we as a people will have to make is a severe one. Most of us tend to look to our local school system for the selection of the talented and for the necessary guidance aids. In perhaps the majority of cases the local school system is too small, too inadequately staffed to do a worth-while job and we shall have to turn to state or government. Indeed this entails a departure from the former easy way of life and from our traditional reliance upon rugged individualism.

Elsewhere in this issue, p. 55, is a portion of a study mission report sponsored by the American Society for Engineering Education and the National Science Foundation on the training of engineers in the USSR. The findings are well worth study and indicate one way student selections are made. Its major objection, to our way of thinking, is that it is evidently a crash program. In the COMBUSTION June 1957 editorial we reported on an attempt here in the USA, a Wisconsin experiment, to uncover superior students as they enter high school and point them toward a development of their skills. Here is a solution, we feel, that lends itself more to our free society than the crash program technique. It uncovers not only the scientist and the engineer but all the other specialties and capabilities so necessary to our way of living. We would welcome a progress report from our Wisconsin friends. But in the meantime we would urge our fellow engineers through their individual societies and the Engineers Council for Professional Development to institute investigative studies of ways and means to uncover our talented youngsters at the start of their high school years.

Use of Flyash in Concrete*

By C. T. WANZER†

Duke Power Company

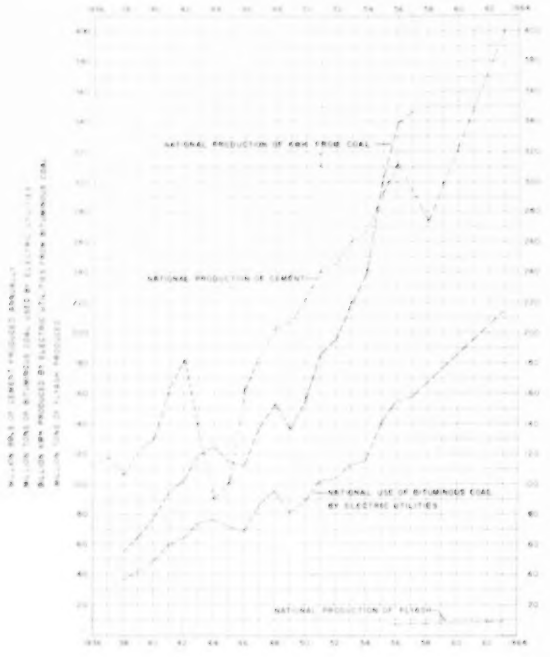

Fig. 13—National annual production of cement for all purposes, electric power, coal usage for power generation, and flyash is charted for overall information

The heavy disposal expense that flyash collections represent to utilities is brought into focus by the author's statistics and considerable data are advanced on the major hope for converting this expense material to a source of income.

FLYASH is a product of pulverized-coal combustion, being that part of the resulting solid residue which is carried in the gases from the steam generator to the stack. The other part of the solid residue is the bottom ash, which is dropped from the bottom part of the furnace as slag or clinkers.

National Production of Flyash

Before discussing the use of flyash in concrete, consideration should be given to the quantity involved, because the tremendous volume was a major reason for trying to reduce the expense of handling this material as a waste product.

National Coal Assn. data show that in 1956 the electric utilities burned nearly 108 million tons of coal in pulverized-coal furnaces only. For the purpose of deriving some very approximate figures, assume that the 1958 coal consumption is 110 million tons and that its average ash content is 10 per cent. The total fly and bottom ash then becomes 11 million tons. A further assumption, that flyash averages 80 per cent of total ash, indicates a production of 8.8 million tons of flyash. Now, if all boilers were followed by ash collection equipment having an average efficiency of 80 per cent, the 1958 recovery of flyash would be 7 million tons. Of course, collectors are not now universally used, and the actual recovery may be much less than 7 million tons.

However, the Oct. 1955 issue of *Electric Light and Power* stated that the electric utility industry, then disposing of 6.1 million tons of flyash annually, would be forced to cope with some 13.7 million tons by 1963. Also, the EEI 1958 report on "Flyash Utilization" says that 6 million tons of flyash, and 9 million tons of total ash, were produced in 1956.

The article "TVA Uses Non-Spec Flyash," in March 1958 *Civil Engineering*, states that TVA's seven modern plants burn over 18 million tons of pulverized coal per year, that 80 per cent of total ash is fly, and that 75 per cent of flyash is recovered in mechanical collectors to the extent of over one million tons per year.

In 1958, the Duke Power Co. will burn nearly 4 million tons of coal in pulverized-coal furnaces only. Since the average ash content will be slightly under 9 per cent, the year's production of total ash will be some 340,000 tons. If flyash is 80 per cent of total ash, the Duke boilers will make around 260,000 tons of flyash. There are mechanical or electrical separators on some units at five of these steam plants, and it is estimated that 210,000 tons of flyash will be collected in 1958.

It is not necessary to establish an accurate figure of national annual production, but merely to point out that, whatever the actual tonnage may be, it is a tremendous volume whose disposal is a direct operating cost.

Flyash Disposal Cost

A few examples will indicate the dollar extent of this disposal burden.

In a paper before the ASME in 1949, H.S. Walker presented data summarized from a questionnaire of 79 utilities, including practically all of those which were then burning pulverized coal. It was shown that, in 1948, these utilities collected 2,242,000 tons of flyash, and

* Presented to the Southeastern Electric Exchange, Roanoke, Virginia, Oct 21, 1958.

† Vice President

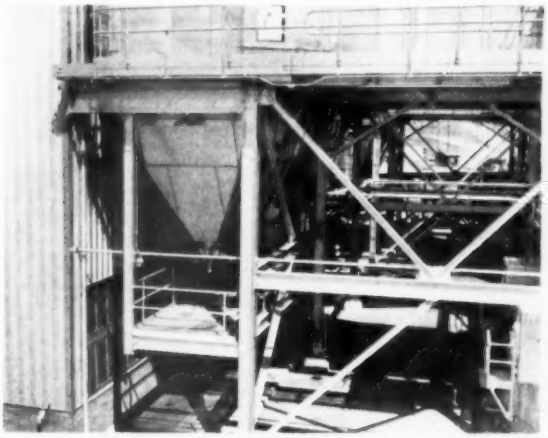

Fig. 1—Flyash collector hoppers on two 175,000-kw units at the Allen Plant of Duke Power Co. are supplying material for concrete needs

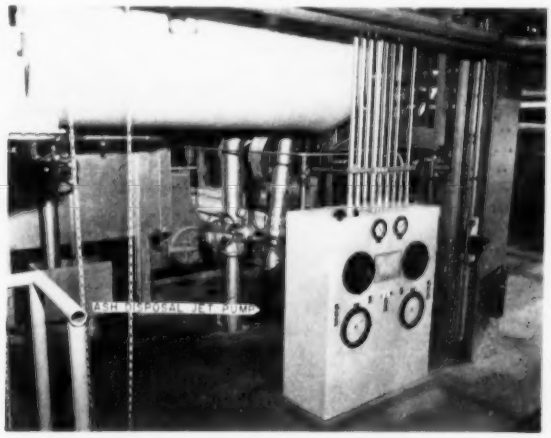

Fig. 2—Ash sluicing pumps receive the hopper discharge to begin the movement of flyash to concrete plant

incurred an average disposal cost of 66¢ per ton.

Electric Light and Power for October 1955 presented disposal costs of 75, 91, 120, and 150 cents per ton for several eastern and midwestern utilities.

The June 1958 issue of *Power Industry* stated that Illinois power plants produce 1.5 million tons of slag and flyash per year, and pay up to $1.25 per ton for hauling.

The EEI report "Fly Ash Utilization" states that 1956 disposal costs ranged from 10¢ to $1.60 per ton, and that an average of $1 per ton is to be expected for disposal by dumping.

These examples indicate that, allowing for probable increases in the cost of former years, it may be assumed that present disposal cost will average well over $1 per ton. To those utilities using ash collectors, the annual disposal cost is so large that development of profitable uses justifies substantial study and expense.

Duke Disposal Method

The storage basins which the Duke Power Co. has built, for storage of combined fly and bottom ash, indicate the size of physical structures involved. Within the last few years, such basins have been constructed at each major steam plant. The design principle is merely the damming up, by earth fill, of a natural, open-end valley. The combined ash is hydraulically conveyed through a pipeline from the powerhouse to storage basin, over distances ranging from 550 ft to 3200 ft.

Table I presents the quantities involved at each of the basins, and shows that the storage of one cu yd of combined ash has required an average of 0.23 cu yd of earth dam, and that one ton of ash required 0.35 cu yd.

Duke's Plant Allen, cover photo, is using its own flyash now in a two-unit extension. Flyash is collected in the hoppers, Fig. 1, drops to the ash-sluicing pumps in Fig. 2 and, joined by the bottom ash, is hydraulically conveyed about 2000 ft to the storage basin in Fig. 3. Without enlargement, this basin will suffice for the ultimate station capacity of over one million kw. The general plan of the Allen Station, Fig. 3a, shows the storage basin.

The cost of this or other method of disposal can be greatly reduced if flyash, some 80 per cent of the total, can be diverted to an income-producing use.

Flyash Dispensing Installations

Several utilities have built the storage and dispensing installations necessary for the sale of flyash at the generating station. The Duke Power Co. has done this at its Dan River steam plant, to serve one 150,000 kw unit. Fig. 4 shows this layout. The silo is 18 ft in diameter and 29 ft high, with a capacity of about 120 tons. It employs a vacuum conveying system, with the receiver and separator on top of the silo. The average production rate is some 2.7 tons per hour, with a maximum of 3.4 tons per hour. It is equipped to load in bulk or in bags. Loading time for a 50-ton car is from 10 to 15 minutes. Eighty-lb bags can be filled at the rate of 150-225 per hour, or 50 to 75 tons per 8-hr day. This complete installation cost nearly $100,000.

Flyash Uses

The preceding indicates the industry-wide need and readiness for uses of flyash which will change it from an expense to an income. Steps in this direction have been

TABLE I ASH STORAGE BASIN DATA

Plant	Year	Acres	Pump Dist Feet	Earth Fills Cubic Yard	Maximum Storage Capacity Of Combined Ash Cubic Yard	Tons	Years	Cubic Yard Fill Per Cubic Yard Ash	Cubic Yard Fill Per Ton of Ash
Dan River	1955	19	600	123,000	531,000	359,000	13	0.23	0.34
Allen	1956	65	1940	411,000	2,360,000	1,595,000	12	0.17	0.26
Buck	1957	37	3230	230,000	1,935,000	1,305,000	24	0.12	0.18
Cliffside	1957	20	550	142,000	433,000	292,000	11	0.33	0.49
Riverbend	1958	69	1980	892,000	2,850,000	1,920,000	17	0.31	0.46
Lee	1958	17	638	310,000	889,000	600,000	17	0.35	0.52
Totals		227		2,108,000	8,998,000	6,071,000		0.23	0.35

TABLE II—MAJOR FLYASH USES IN 1956

Tons	Use
112,000	Replacement of cement in concrete
96,800	Pressure grouting
68,500	Concrete blocks
63,100	Mineral filler in asphalt paving
22,100	Soil stabilization with lime for road base-courses
44,800	All other uses
407,300	Total known use out of an annual production of 6 million tons

Fig. 3—The sluicing lines carry the water and ash mixture to a 65-acre ash storage basin about 2000 ft from the plant

underway for several years, and some of the promising uses are shown in Table II with the 1956 tonnages known to have been actually used.

One of the most interesting flyash applications is that of replacement of cement in concrete, and this will be discussed in some detail, beginning with a brief reference to the pozzolan group, of which flyash is a member.

Flyash Is A Pozzolan

Flyash is a pozzolan. With respect to concrete, a pozzolan is a siliceous or siliceous and aluminous material which has no cementitious value in itself, but which, in finely divided form in the presence of water, will combine with calcium hydroxide at ordinary temperatures to form cementitious compounds.

Pozzolans may be natural or artificial in their formation. Natural pozzolans include diatomaceous earths, opaline cherts and shales, volcanic ash or pumicite, and the tuffs. The most important artificial pozzolan is flyash which, as stated before, is that part of the solid residue which results from the combustion of pulverized coal, and which is carried in the gases from the steam generator to the stack.

Early Use of Pozzolans

While flyash in concrete is fairly modern, the use of other pozzolans began nearly 2000 years ago. As early as 12 A.D., volcanic ashes were combined with lime for all types of masonry. The Romans used a volcanic tuff found near Pozzuoli and called pozzolana. Still in existence are many buildings, roads, aqueducts, etc, built of stone blocks bonded by a pozzolan, quicklime, and water.

Transition From Pozzolan to Cement

There was no substitute for pozzolanic mortars until 1756, when a hydraulic cement was made in England from a clayey limestone. Portland cement was also first developed in England around 1800, and was patented under that name in 1824. In the United States, the first product was a natural cement, made from cement-rock in New York state. It was patented in 1818, and became a commercial product in 1850. Portland cement was first made in this country in 1875. Now, after nearly 2000 years, we are returning to flyash, a close relative of the original cementing material in masonry.

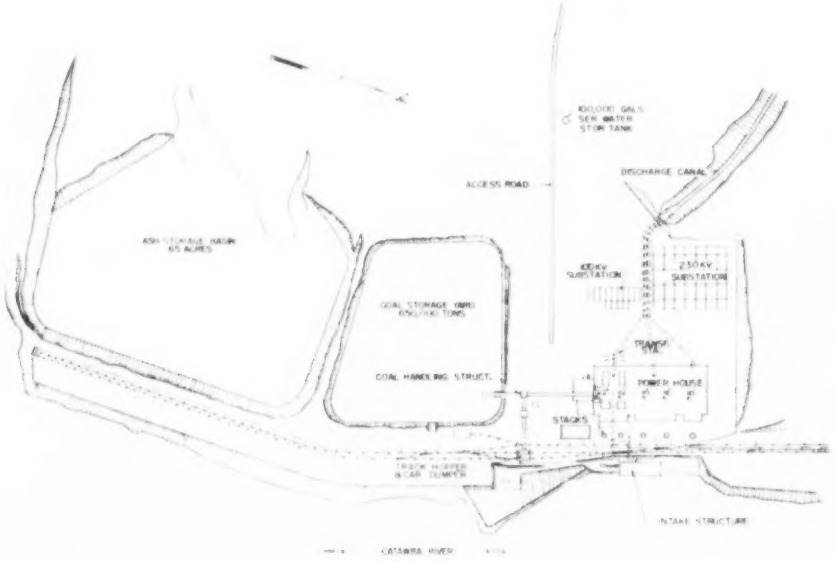

Fig. 3a—The general plan of the Allen Station shows the relation of the storage basin to the other structures

TABLE III CONCRETE STRUCTURES WITH FLYASH OR POZZOLANS OR POZZOLANIC CEMENT

Reclamation Dams			Other Dams			Other Structures			
Year	Name	Mill CY	Year	Name	Mill CY	Year	Name	Structure	Thou CY
'38	Shasta	6.50		U. S. Engr:		'10	Los Angeles	Aqueduct	
'40	Friant	2.14	'35	Bonneville	1.17		Golden Gate	Bridge	
'43	Altus	0.07	'57	Sutton	0.50	'54	Springdale	Steam Plant	
'46	Davis	4.36				'55	Cromby	Steam Plant	
'48	Hungry Horse	3.09		Others:		'56	Shippingport	Steam Plant	
'51	Canyon Ferry	0.41	'52	Liberty			Johnsonville	Steam Plant	50
'55	Monticello	0.33	'53	Hoover		'58	Allen	Steam Plant	38
'57	Glen Canyon	5.06	'56	Priest Rpd.	0.38		Wilson	Lock	450
'58	Flaming Gorge	0.92							

Effects of Flyash in Concrete

After considerable experience with flyash in concrete, it is fairly well agreed that its partial replacement of portland cement will produce the following results:

Favorable
- Workability improved
- Water content reduced
- Bleeding largely eliminated
- Density increased
- Permeability decreased
- Compressive strength increased after 90 days
- Heat of hydration reduced
- Alkali-aggregate reaction prevented
- Freeze-thaw resistance possibly increased
- Volume change possibly reduced

Unfavorable
- Compressive strength decreased at 7 and 28 days
- Curing requisites increased at early ages
- Air-entrailing agent increased for required air percentage
- Handling more difficult than cement

Dams With Flyash. The beneficial effects of flyash in concrete were recognized in 1933 when it was investigated, but not actually used, for Grand Coulee dam. Table III shows some of the major structures and concrete yardages in which flyash or pozzolans have since been incorporated.

Flyash Is Accepted Admix. The data in Table III shows that flyash is an accepted ingredient of concrete. However, it cannot be used indiscriminately because it is not a uniform product, as will be shown in the following.

Chemical and Physical Characteristics

One reason for examination of specification requirements is that there must be familiarity with the product if it is to be sold or used by the producing utility. Flyash, as a part of the complex mixture known as concrete, is too new in that role to be used without careful analysis to determine if, in fact, a particular ash will properly blend with the other ingredients of a particular concrete. Therefore, since the fitness of an ash is determined by standard specifications, their requirements should be known.

Table IV shows some of the specifications controlling the use of flyash in concrete, and presents similar data

TABLE IV CHEMICAL AND PHYSICAL CHARACTERISTICS OF FLYASH FOR USE IN CONCRETE

	SiO_2, Min, %	Al_2O_3, Min, %	MgO, Max, %	SO_3, Max, %	Ignition Loss, Max, %	H_2O, Max, %	Alk., Max, %	Spec. Surf, Min, %	Retd. 325, Max, %	Spec. Grav.	Comparative Strength, Min, %[a]	Shrinkage, Max, %	Expansion, Max, %
Specifications													
ASTM Spec. C350-54T	40		3	3	12	3	1.5	2800			100	0.10	0.50
ASTM Spec. C350-57T	70	[b]	3	3	12	3	1.5	2800			100	0.10	0.50
Bureau of Reclamation	70	[b]	3	4	5	3		3000	12		85	0.03	
Flaming Gorge Dam	75	[b]	5	4	5	3	2	3000	15		85	0.04	
Priest Rapids Dam	50				10	3	1.5		12		75	0.15	
Intrusion Prepakt Co.	40	15	3	3	5	2		3000	12	2.3 mi			
City of Chicago	42	15	3	3	6	1		3000	12				
Hungry Horse Dam	40	15						3000					
Sutton Dam	70	[b]	3	3	6	3	1.5	2800			75	0.03	0.50
Actual Flyashes													
Avg of 34 ashes[c]	44.1 82.4	20.8 [b]	1.2	1.3	7.8			3673		2.4			
Avg of 16 ashes[d]	39.9	24.0	1.0	1.1	12.1	0.27	0.94	2640	21	2.32			
Dan River No. 3													
Test 1	49.6		0.94	Tr.	5.3	0.05	0.92	2500		2.15	150	0.03	0.07
Test 2	44.2		1.23	0.25	10.1	0.16	0.58	3090		2.06	122	0.08	0.03
Test 3	45.5		1.17	Tr.	10.9	0.04		3665		2.39	116	0.04	0.01
Allen No. 2[e]													
Test 1	47.0		1.26	Tr.	6.0	0.09	0.81	8685					
Test 2	44.8		1.64	0.17	3.1	0.04	0.60	1610		2.19	144	0.08	0.01
Test 3	45.3		1.97	Tr.	3.7	0.05		2660		2.25	113	0.05	0.07
Colbert, T.V.A.[e]	42.5	18.8	1.1	0.9	3.5		0.40	1750	40	2.46			

[a] Compressive strength of flyash mix at 28 days is the listed per cent of the control mix with no flyash.
[b] Figure in the SiO_2 column is the minimum total for SiO_2 plus Al_2O_3 plus Fe_2O_3.
[c] Brink and Halstead—Studies Relating to the Testing of Flyash for Use in Concrete.
[d] Davis and Assoc.—Properties of Cements and Concretes Containing Fly Ash, 1937.
[e] Mechanical flyash collectors.

for some flyashes which have been used in actual structural concrete. Some of these characteristics deserve special attention, either because of inherent importance or because of difference of opinion relative thereto.

Why Flyash Is Cementitious

The second part of the flyash definition is most important: namely, that it combines with calcium hydroxide to form cementitious compounds. Calcium hydroxide is one of the early and major compounds produced by the hydration of portland cement. The calcium-flyash reaction is the reason why flyash can replace cement. If it did not possess this property to form cementitious compounds, it would be a mere inert material, and the cement content of concrete could not be reduced therewith. In spite of very extensive chemical research, much is still unknown about how, and in what sequence, the various flyash elements combine with calcium hydroxide and the other early products of cement hydration. Of the three major ash ingredients—silicon dioxide, aluminum oxide, and iron oxide—it is now thought that silicon plays the major part, and that the main product of hydration may be a calcium silicate. But there are also complex compounds of aluminum and iron, particularly the former, and the ASTM specification relative to the required percentages of these elements was recently changed. The total chemical process between flyash and cement is called the pozzolanic action, and its existence is the only reason for flyash acceptance as a cementing material.

Ignition Loss (Carbon)

Loss of ignition is now a standard test, replacing that of carbon content. Percentages of carbon and ignition loss are nearly identical, with ignition loss being slightly greater since it includes both carbon and any other substance lost in the ignition test. Brink & Halstead's "Studies Relating to the Testing of Flyash for Use in Concrete" in the Feb. 1957 issue of *Public Roads*, develops the carbon-ignition loss relation, which is shown in Fig. 5. This indicates that an ignition-loss percentage will be only slightly larger than the carbon content of the same ash, and it will be assumed in this discussion that the percentage of ignition loss represents, and closely approximates, the carbon content.

Effect of Carbon Content

The carbon content of flyash is very important because it is widely accepted that low carbon is necessary for a satisfactory concrete-flyash. As present in flyash, carbon is simply coke in the form of gritty and porous particles of irregular shape. The other ingredients of flyash are very small glassy spheres of complex chemical composition which unite with calcium hydroxide to form cementitious products, and are beneficial to combination with the compounds of hydrating cement. Carbon is undesirable (1) because it reduces concrete strength due to the fact that its porous formation increases the water content, and (2) because carbon in any amount reduces, by that amount, the percentage of beneficial materials.

Brink & Halstead proved (1) that mortar strengths at both 28 and 90 days are greater with a carbon-free flyash than with one having from 1 to 15 per cent carbon, and (2) that, with cement replacements of 10, 20, 35, and 50 per cent, mortar strengths decreased as carbon increased. This fact was indicated as a trend rather than a pronounced or large difference.

Effect of Fineness

The first comment on fineness is that no present test seems to produce entirely satisfactory results. This is unfortunate because fineness is one of the most important characteristics in the determination of the fitness of flyash for use in concrete. Possibly the most widely used

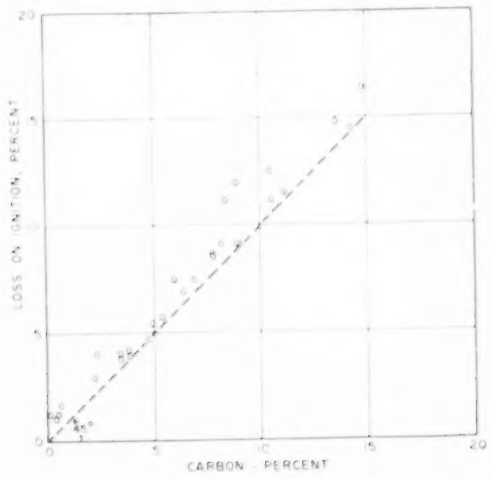

Fig. 5—Above curve from a Brink and Halstead paper referred to in the text shows close correlation between carbon loss and ignition loss

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Fig. 4—Dan River Plant of Duke Power Co. has built for one 150,000-kw unit a flyash storage and dispensing unit to expedite sale of flyash

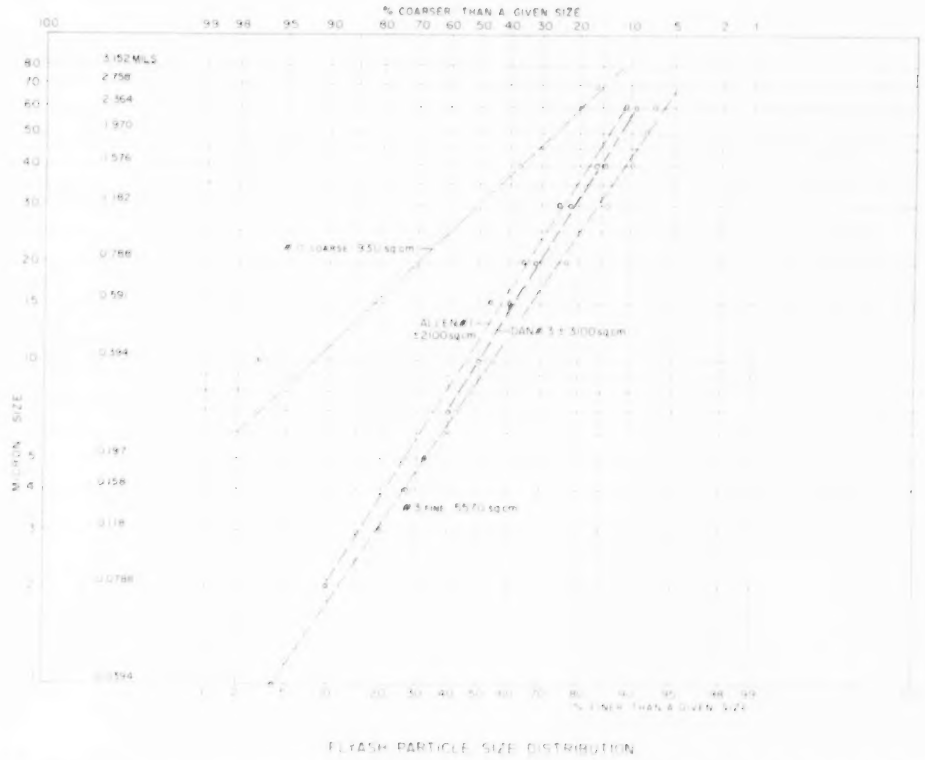


Fig. 5a—Samples marked Allen No. 1 and Dan River No. 3 are from mechanical collecters, No. 15 coarse and No. 3 fine are the coarsest and finest of the 34 samples investigated by Brink and Halstead

method of test is that of the Blaine air-permeability method, but the hydrometer and the No. 325 sieve are also used, with the sieve method gaining in popularity. In their exhaustive study, Brink & Halstead measured flyash sizes by each of these three methods, and favor the sieve because their data indicates that the permeability method is likely to furnish misleading information. This is because, for a group of 34 flyashes, air permeability showed that the finest ashes were those with the most carbon, while the hydrometer and sieve showed that the finest ashes were those containing relatively little carbon, which is probably the fact.

One possible reason for this discrepancy is as follows: Photomicrographs show the inorganic portions of the ash as dense and glassy spherical particles. The carbon particles, on the other hand, are highly porous, larger, and of irregular shape. It is probable that the air permeability test measures not only the carbon's exterior surface, which is the area sought, but also part of the internal surface of its porous formation. If this be fact, the test will show that an increase in carbon content produces an apparent, but erroneous, increase in total surface of the flyash, indicating a finer material, even through the external surface and consequent fineness are actually less, thus making a coarser ash.

This same study showed that, when fineness determined by the permeability or hydrometer methods was plotted against compressive strength, there was no definite relation between the two. However, by using results of the sieve method, the graph showed an increase of strength with increase of fineness. This disagreement merely throws further doubt on the accuracy of the permeability method. Even the hydrometer results, when confined to particles less than 0.03 mm (30 microns) in diameter, showed the same general relation between strength and fineness.

The discrepancy between methods of fineness determination has been here emphasized because it is one of the most important factors in the specifications of flyash for concrete. Therefore, if flyash sale is dependent upon meeting a specific fineness, it is necessary that the method of fineness determination be specified in the knowledge of its inaccuracies.

Fig. 5a is a graph of particle size distribution of several flyashes. The ones marked Allen No. 1 and Dan River No. 3 are from mechanical dust collectors. The lines identified as No. 15 coarse and No. 3 fine are from the Brink and Halsted Study (PUBLIC ROADS for Feb. 1957) and show the finest and coarsest ashes of the 34.

The influence of carbon content on fineness of flyash is well illustrated by one example from Davis' 1937 experiments, showing a high-carbon means a coarse ash:

	C, %	Retd. on 325 Sieve, %	Finer Than 10 Microns, %	Spec. Surf.
Avg of 3 fine ashes	2	10	33	2750 sq cm/gm
Avg of 5 coarse ashes	22	30	20	2150 " " "

It is generally accepted that fine flyashes make concrete with higher compressive strengths than do coarse ashes. However, the fact that increasing fineness produces increased strength does not mean that a relatively coarse ash produces low-strength concrete, or is unacceptable for use in good concrete. This statement is borne out by Duke and TVA use of fairly coarse ashes. It is also proved by Davis' 1937 work, reported in his "Properties of Cements and Concretes Containing Flyash." It is

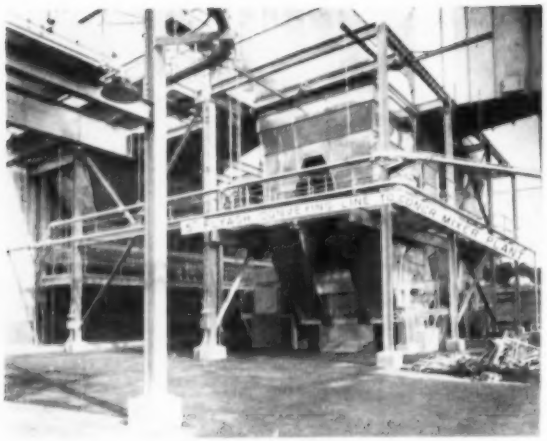


Fig. 6—A decision to lead flyash direct from Allen Plant boilers of Fig. 2 to a concrete mixing plant as well as to ash storage required installation of a flyash conveying line

there shown that 28-day and 1-year compressive strengths of concrete made with coarse ash, 1730 sq cm/gm, averaged 3890 and 5630 psi, which are excellent figures even though they are less than those produced by fine ashes of 3220 sq cm.

Effects of Flyash on Water Content

For a given concrete slump, it is generally true that natural pozzolans require a water content greater than that for plain concrete, but this is not true of flyash, particularly those of low carbon and high fineness.

The Brink-Halstead study found that, with 35% cement replacement, the required water content generally increased with an increase of carbon in the flyash.

Flyash for Plant Allen Concrete

The discussion of flyash specification requirements having been completed, attention is now turned to a specific use of flyash in concrete which is now being produced.

After Allen units Nos. 1–2 went into operation in late 1957, their flyash was removed by mechanical-type collectors, and pumped to the ash storage basin. At that time, construction of three more units was scheduled to follow during the period 1958–1960. For those units, some 38,000 cu yds of concrete were to be made in a mixing plant on the job. With an estimated average of 12–14 tons of flyash being wasted each hour, it was decided to develop a temporary method of transporting some of this ash from the collector hoppers to the concrete mixing plant.

The beginning of the system is a valve in the header under the collector hoppers, as shown by Fig. 6. Ash is conveyed from this point thru 5-in. and 6-in. pipes, Fig. 7, under a nine-inch vacuum, to the concrete plant. The vacuum is produced by a water jet which, with other equipment and the ash silo, is shown in Fig. 8 where the equipment is named. At the top of its bucket elevator, the flyash may be diverted to the silo for storage, or to a chute for loading cars and trucks, Fig. 9. From its bin on top of the mixing plant, the ash passes through a batcher, Fig. 10, into the mixer and to the concrete pump, Fig. 11. The discharge of concrete from the pipe into the forms is shown in Fig. 12. The total cost of this plant was $29,000 of which $20,500 was for equipment, and $8500 for erection labor.

Duke Concrete Mix Comparison. Table V shows details of two concretes, one plain which had been previously used at Allen, and one with flyash. Cement was

Fig. 7—The flyash conveying pipe, 5-in. and 6-in. diam, operates under a 9-in. vacuum to move the material

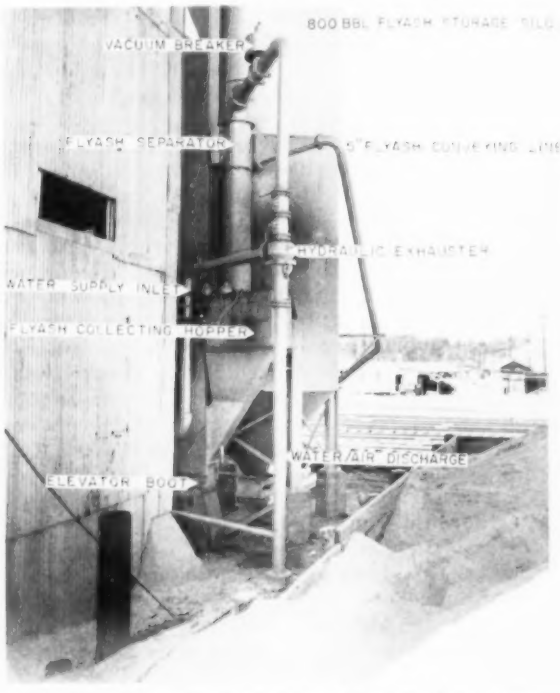


Fig. 8—The water jet producing the vacuum plus certain other of the vacuum and ash storage equipment appears in this photo

replaced in the amount of 25 per cent by weight of that used in the plain mix. In pounds, cement was reduced from 470 to 353, the difference of 117 being replaced by an equal weight of flyash.

Several interesting results are shown with respect to the physical mix:

1. Sand content is usually reduced when flyash is used, but in this case there was an increase of 57 lb.

2. Coarse aggregate increase of 25 lb is nominal.

3. Water content was reduced by 5.8 gal per cu yd, a drastic decrease reflected in the drop of water-cement ratio from 0.58 to 0.48. The water-cement ratio is actually W/C+FA, where W is water; C, cement; FA, flyash.

4. The 7-day compressive strength is somewhat unusual in that, instead of being less than that of the corresponding plain mix, it is slightly larger. However, the small difference of 32 psi is within the range of testing error.

5. The 28-day strength follows the expectation that it should be slightly less than for its corresponding plain mix.

6. The 90-day strength, in its 483 psi increase over the plain mix, shows that pozzolanic action is under way.

Duke Concrete Cost Comparison. Table V also shows that, for these particular ingredients and proportions, the use of flyash resulted in a saving of $1.06 per cu yd. Labor costs are not included because they are the same for both mixes.

The flyash plant depreciation cost of 5¢ per cu yd is based on a 6.7 per cent annual rate for 1.5 years during which only 38,000 cu yd of concrete will be made.

Flyash Prices for Other Concretes. One of the main reasons for use of flyash in concrete is the consequent cost saving, of which a major part is the cheapness of the ash itself.

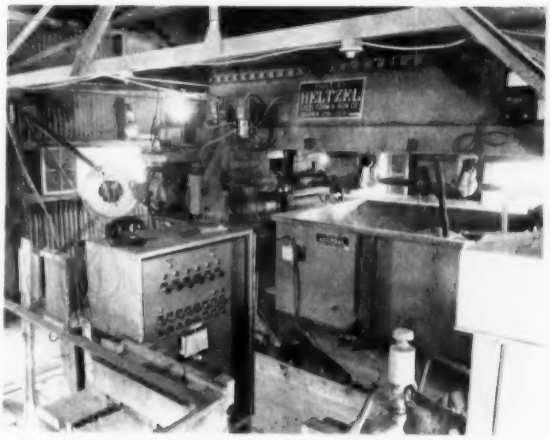


Fig. 10—Special batcher permits feeding the flyash to the concrete mixer in described amounts

The situation at Allen is unusual in that the transportation cost is practically nil, while the ash cost is an assumed $1.50 per ton. The Canyon Ferry dam used 22,600 tons at $1.40 per ton f.o.b. shipping point. Hungry Horse dam required 140,000 tons at $11.50 per ton of which $10 was freight. Both of these jobs, therefore, paid around $1.50 per ton f.o.b. origin.

The EEI Fly Ash Uses states that recent prices range from nothing to $2 per ton in bulk, and $5.6 in bags. The October 1955 issue of *Electric Light and Power* states that one utility sells bulk at $2, and bagged at $5 per ton, but $3 if customer furnishes the bags; and that a midwest utility sells at $1.50 bulk and $4 bagged.

Flyash and Cement Costs Compared. For comparison with cement, the cost of flyash is here assumed as $7.30

TABLE V—COMPARISON OF ALLEN CONCRETES WITH AND WITHOUT FLYASH

	No Ash	With Ash	Difference
Materials Per Cubic Yard of Concrete			
Cement lb	470	353	−117
Flyash lb	0.00	117	+117
Sand lb	1158	1215	+57
Stone lb	2032	2057	+25
Water gal	33.0	27.2	−5.8
Pozzolith lb	2.5	2.5	0.0
W/C ratio	0.58	0.48	−0.10
Air per cent at mixer	[a]	5.5	
Air per cent at forms	4.8	3.0	−1.8
Slump at mixer	[a]	5.7	
Slump at forms	5.2	2.7	−2.5
Sand/tot agg. per cent	36.3	37.1	+0.8
7-day compr. psi	2233	2265	+32
28-day compr. psi	3708	3648	−60
90-day compr. psi	4468	4951	+483
Material Cost Per Cubic Yard of Concrete			
Cement	$5.20	$3.90	−$1.30
Flyash	0.00	0.09	+0.09
Sand	1.39	1.46	+0.07
Stone	2.44	2.47	+0.03
Pozzolith	0.85	0.85	0.00
Depreciation	0.00	0.05	+0.05
Totals	$9.88	$8.82	−$1.06[d]

[a] 5.00, 3.75, 1.25 bags.
[b] 275, 227, 48 lb.
[c] For flyash plant only.
[d] Net in favor of flyash.

Fig. 9—The flyash moves by bucket elevator to the top of the storage silo for entry to the silo or routing by chute to loading cars or trucks

Fig. 11—Concrete pump is employed to direct finished concrete to desired site

Fig. 12—View above shows the concrete mix being discharged from a pipe to the forms

per ton delivered in bulk to a jobsite 350 miles from Charlotte N. C., composed of $1.50 for the ash and $5.80 for freight. This is 0.004 per lb f.o.b. job. A corresponding delivered cost of cement might be about $4.40 per bbl, or 0.012 per lb.

The difference is 0.008 per lb in favor of flyash.

While these are imaginary figures, they may be used to derive an interesting figure, as follows: Assume that 25 per cent of the cement in a 5-bag mix is replaced by flyash, amounting to 117 lb per cu yd of concrete. This 117 lb would cost $1.40 as cement, and $0.47 as flyash, resulting in a cost reduction, due to this one item only, of $0.93 per cu yd of concrete.

Assumed Cement & Concrete Production. Fig. 13 shows the national annual production of cement for all purposes from 1936 through 1957 as recorded by the Bureau of Mines. On this chart, production is projected to 1963. This is not an official or authoritative estimate; it is made arbitrarily for the sole purpose of arriving at a purely speculative output five years hence.

The annual amount of cement now used in concrete is a matter of record, but the amount to be used in future flyash concrete is most uncertain. If it be assumed that the larger ready-mix concrete plants will be equipped in 1963 to handle flyash, then 50 per cent of the total cement production might be used in concrete susceptible to incorporation of flyash. This would result in a potential use in 1963 of 200 million barrels of cement in flyash concrete. (See Fig. 13, p. 38)

Possible 1963 Use of Flyash in Concrete. The percentage of concrete cement replaced by flyash can be estimated with some degree of accuracy. For the purpose of this prediction of flyash potential use, it is placed at 25 per cent by weight. Since the 200 million bbl of cement weighs 38 million tons, the possible amount of replacement flyash is some 9 million tons.

This usage can be roughly checked by another curve Fig. 13, which shows that the bituminous coal burned in 1956 by the steam-electric stations produced about 6 million tons of flyash. If coal usage in 1963 should be 214 million tons, application to it of the known 1956 coal flyash ratio would indicate a 1963 flyash production of over 8 million tons.

End of Costly Flyash Disposal? If, by chance, these guestimates should prove to be even approximately correct, the mid-1960's would see the total annual flyash production about equal to its market in the single field of concrete. Even should this be not true for concrete alone, other flyash uses are almost certain to increase, possibly to the point where their total demand will require the total amount produced.

This is merely an interesting speculation, with no pretense of accurate prediction. But the figures indicate that, not many years in the future, the use of flyash in concrete alone may produce a very large reduction in trouble and expense of flyash disposal.

Commerce to Publish Semi-Monthly Directory of Available Translations

The Department of Commerce were to begin publication in January of a periodical planned to serve as a central source of information in the United States on Russian and other technical translations available to science and industry, according to John C. Green, director of Commerce's Office of Technical Services.

The periodical, *Technical Translations*, will be published twice a month by the Office of Technical Services, in cooperation with the Special Libraries Association. It will list and abstract translated material available from U. S. Government sources, SLA, cooperating foreign governments, educational institutions and private sources, Mr. Green said.

"As part of the cooperative arrangement between OTS and the Special Libraries Association," Mr. Green commented, "SLA's *Translation Monthly*, familiar to all who have been working with translations, will be incorporated in *Technical Translations*. Through this OTS-SLA cooperation *Technical Translations* will serve science and industry as a central, time-saving directory to translations completed or in process by many sources."

By IGOR J. KARASSIK*

Worthington Corp.

The boiler feed pump and its associated equipment represent a major operating and maintenance consideration in today's power plant. Here we run in question and answer form a series of clinic sessions on various boiler feed pump problems. The replies are the work of one of the topmost pump authorities and give specific information which we hope will prove valuable to our readers.

Steam Power Plant Clinic—Part VI

QUESTION:

We are operating a combination heating and power plant for an institution. Our present problem involves the coordination of a new 350,000 lb per hr deaerator which will furnish feedwater to a new 700 psi, 825 F boiler and to a group of older boilers operating at 200 psi, 480 F. We are planning to install a single boiler feed pump suction header from which the two groups of pumps will take their suction. The low pressure feed pumps will be located directly below the deaerator with comparatively short suction piping, but the high pressure pumps will require a horizontal run of approximately 120 ft. There are three low pressure pumps, all with a rating of 300 gpm at 675 ft total head. The pumps will operate under a 19 ft static head from the normal water line in the heater to the pump centerline. No trouble has been experienced with boiler feed pump suction up to this time, but the maximum plant load is increasing. It has been around 150,000 lb per hr and may approach 200,000 lb per hr next heating season. The high pressure boiler is rated at 125,000 lb per hr. The high pressure boiler feed pumps will be located at a lower level, so that they will have about 12 more feet of static head available. We plan to install 10 in. suction header piping for a maximum capacity of about 400,000 lb per hr. The heater outlet size is specified as 12 in. The heater will be operated at approximately 5 psig and will be pegged at that pressure.

Do you know from your experience of any troubles which may develop with boiler feed pumps operating at different discharge pressures but taking their suctions from the same suction header? We remember reading one of your articles which mentioned four items which affect suction conditions: heater storage level above the pumps, friction head losses in the piping, NPSH required by the boiler feed pumps and the internal volume of the connecting piping between the heater and the pumps. We feel that we have properly taken care of the first three items. Could you comment on the significance of the fourth item?

ANSWER:

With specific reference to your second question, that is, the effect of the internal volume of the suction piping between the deaerating heater and the boiler feed pumps, I can advise you that it will not enter into the problem you have described, since your heater will operate at a "pegged" or constant pressure. This volume plays an important part in installations where the deaerating heater is fed with steam bled from an uncontrolled stage of the main turbine and, therefore, is said to be "floating on the line" with the load. As the pressure of the steam feeding the heater varies almost in direct proportion with the load, you can readily visualize that abrupt changes in load will always lead to equally abrupt changes in the steam pressure supply to the heater. Thus, following a sudden drop in main turbine load, the bleed stage pressure will fall off more rapidly than the pressure in the heater itself. At that juncture, the check valve between the turbine and the heater will close. With no further steam supply, with cold condensate still entering the heater and with hot feedwater being still withdrawn from the heater storage, the total heat content in the heater storage will be reduced and flashing will take place in the heater. This flashing will, of course, be followed by reduced pressure and temperatures, until such time as the pressure in the heater will have stabilized at the pressure of the bleed stage or slightly below, the check valve will reopen to resume stable operation.

But since pressure is transmitted instantaneously, the pump suction pressure will fall off as rapidly as the pressure in the heater itself. On the other hand, the water which now leaves the heater storage at a progressively lower temperature will take some time before it finally reaches the pump. This time element, of course, will be a function of the volume in the suction piping and of the rate at which feedwater is withdrawn from the heater by the boiler feed pump. It is this time lag between the pressure reduction at the heater and the temperature reduction at the pump suction which can lead to serious difficulties during the transient conditions which follow a sudden load drop at the main turbine.

The problems encountered during such transient conditions have been treated in great detail in a paper presented to the ASME in 1953.† They are not in

* Consulting Engineer and Manager of Planning, Harrison Div.

† "Centrifugal Boiler Feed Pumps under Transient Operating Conditions" by Igor J. Karassik, George H. Beckworth and Warren D. Ellison, presented at ASME Fall Meeting, October 1953, Rochester, N. Y. — Worthington reprint No. RP 702

volved here, however, since the heater pressure is fixed. Therefore, you need not be concerned with the volume of the suction piping in your installation.

With regards to the first question, I can assure you that there is no problem which can arise from the operation of two sets of pumps, designed for different discharge pressures and taking their suction from a common header and a common deaerating heater, as long as proper NPSH requirements are observed. This is true both from a theoretical consideration of the situation and from all available experience.

It remains to check the actual conditions prevailing at the suction of these two sets of pumps. If you use a 10 in. suction line for a maximum flow of 400,000 lb per hr (840 gpm at the 228 F corresponding to the 5 psig heater pressure) the friction losses will be 0.75 feet approximately per 100 feet of pipe. This is certainly a reasonable figure. Your low pressure pumps, as you state, have had no troubles. There should be likewise no difficulty with the higher pressure boiler feed pumps since 12 feet additional static head is available for these.

QUESTION:

Our steam power plant uses a closed feedwater cycle and the condensate pumps discharge directly into the boiler feed pumps through closed heaters. The turbo-generator, rated at 156,000 kw, operates at a pressure of 1850 p.s.i. Three condensate pumps and three feed pumps are installed, of which two operate for full load conditions, the third condensate and feed pump remaining on standby duty. We are not certain what means should be employed to protect the boiler feed pumps against possible failure of condensate pump discharge pressure. What is the best solution for this problem?

ANSWER:

This is a rather thorny problem, because several methods are used in different plants and they each have their respective merits. The preferred solution is generally dictated by the personal preferences of the designing or operating personnel. I can outline several of these approaches and give you general comments on their respective effectiveness, letting you judge between them and select your own preferred method.

In general, the discharge pressure of condensate pumps serving a closed cycle is selected in such a manner that the suction pressure at the boiler feed pumps provides an excess over the minimum NPSH required by the boiler feed pumps over and above the maximum vapor pressure which may occur at that point in the cycle.

However, failure of the condensate pumps can obviously occur independently of the conditions prevailing at the boiler feed pumps. Not only can the condensate pumps themselves fail, but their drivers or the power supply to these drivers can fail independently of the power supply to the feed pump drivers, since the two generally operate on different voltages.

Failure of condensate supply in an open cycle presents no major hazard, since the deaerator storage will normally permit the boiler feed pumps to continue operating for 5 to 15 minutes, depending on the operating load and the size of the storage tank. This is sufficient time to reestablish condensate pump operation or to bring the main unit down and shut the boiler feed pumps. But there is no such safety margin in the case of the closed cycle. And since failure of feedwater supply at the suction of the boiler feed pumps cannot be tolerated, some protective means must be provided to avoid this condition.

Generally, today's operating pressures and temperatures at the boiler feed pump suction preclude the use of storage tanks which could act as surge tanks floating on the suction line and ready to supply water to the feed pumps in the event of condensate supply failure, since the necessary static elevation of such tanks would be beyond any practical limits. On the other hand, certain recent observations of the behavior of flashed feed pumps may lead to a re-evaluation of this means of protection. It has been noted that if the design of the boiler feed pumps is such that the shaft deflection is considerably less than the internal clearances and that no dependence is made on the internal joints to act as water lubricated bearings, it is far safer to let the pump run in a flashed condition than to shut it down while it is still steam-bound.* In such a case, then, it is recommended that efforts be made to re-establish water supply to the pump suction rather than to stop the pump and bring it to rest. If such a philosophy of operation is accepted, then a cold water surge tank can be installed and would act to ultimately restore water supply to the boiler feed pump.

For instance, assume that the boiler feed pumps handle 320 F feedwater (vapor pressure = 75 psig, specific gravity = 0.908) and that the minimum required NPSH is 50 feet. The minimum permissible suction pressure will be 95 psig. A surge tank can be installed as shown on the attached illustration, Fig. 1, and a check valve would be installed in the piping from the surge tank to the suction header, as shown. On failure of condensate supply, the suction pressure will drop and the boiler

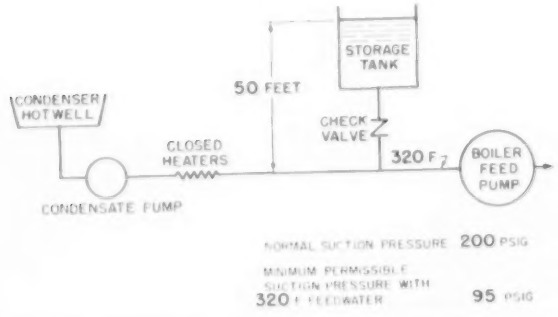


Fig. 1—Arrangement of surge tank in closed feedwater cycle to permit reestablishing water supply to the pump suction in case of flashing

* See "How Do You Operate Your Boiler Feed Pumps?" by I. J. Karassik, Power Engineering, March 1957, Worthington reprint RP-923.

feed pumps will flash. At some point during this transient condition, the suction header pressure will be reduced sufficiently so that the check valve will open, cold water will flow into the header and the boiler feed pumps will reprime themselves. If condensate supply cannot be re-established after a reasonably short time interval, the unit can be shut down and secured as would be the case if the steam plant employed an open cycle. The illustration indicates an elevation of 50 feet for the storage tank level and this is, of course more than ample to provide 50 feet NPSH with cold water.

This arrangement is extremely simple, and therefore extremely tempting. At the same time, it presupposes that the boiler feed pumps are capable of operating for a short while in a flashed condition—and this should be thoroughly checked with the pump manufacturer. It is possible, however, to modify this arrangement so as to provide more assured protection in the event of condensate supply failure and still avoid elevating the surge tank beyond reasonable means. The modification would consist in providing a pressurizing source for the surge tank, so arranged that the pressurization would take place immediately on a marked reduction of condensate discharge pressure. The most acceptable arrangement would be to install a pressure reducing station, set to open the surge tank to steam admission whenever the boiler feed pump suction pressure fell below a predetermined minimum. For instance, in the case illustrated here, since the normal pressure is 200 psig and the minimum safe pressure is 95 psig, pressurization of the surge tank with steam would be set to occur whenever the boiler feed pump suction pressure fell to 150 psig.

Another, more frequently used approach is based on the thought that complete failure of condensate to the boiler feed pump will cause a complete failure of the latter in a matter of seconds and that it is best to cut one's losses short. Consequently, failure of feed pump suction pressure is made to stop the feed pumps, letting boiler protective controls take care of the boiler problems. The condensate pump discharge pressure is selected to provide some excess over the minimum permissible feed pump suction pressure. If the suction pressure falls below the normal value, but still above the minimum, a pressure switch starts the standby condensate pump, in the hope that this will arrest any further decrease in suction pressure. If, however, this maneuver fails to solve the problem, as the suction pressure is further reduced, a second pressure switch simply cuts the power supply to the boiler feed pump drives and brings the pumps to rest.

For instance, in the case illustrated, Fig. 1, the first pressure switch may be set at 175 psig and the second at, say, 125 to 150 psig. Thus, if suction pressure falls to 175 psig, the standby condensate pump is started and if the pressure falls further to 150 psig, the boiler feed pumps are stopped.

A time delay relay should be incorporated in this second switch to take care of the time lag in re-establishing suction pressure by starting the standby pump. It is difficult to predict the exact duration of flashing which can be permitted to occur in a pump before damage will take place. But five seconds are generally considered as sufficient to restore pressure if the standby condensate can do it and not overly long from the point of view of the feed pump safety.

The choice between these various methods is, as I have already stated, somewhat subjective. The most satisfactory choice can only be made, however, after consultation with the manufacturers of your boiler feed pumps.

Oil Industry in Year-End Report

On the eve of the industry's centennial anniversary, Frank M. Porter, president of the American Petroleum Institute, announced that domestic demand for oil products would reach another all-time peak in 1958—up about 1½ per cent over 1957.

This represents the 16 th consecutive year that domestic demand has topped the previous year—but President Porter cautioned against misinterpretation of this fact because total demand, which is more accurate as a barometer of oil's overall operations, will be down for the first time since 1946.

Total demand—which includes exports—will be off about 1¾ per cent. Explanation for this decline, is to be found, at least in part, in the fact that European demands upon U. S. petroleum supply, as a result of the Suez crisis, caused the American industry's 1957 foreign shipments to show totals considerably higher than would normally have been expected for this period.

The 1958 exports, in comparison, therefore, showed an anticipated large decline, and affected this year's total.

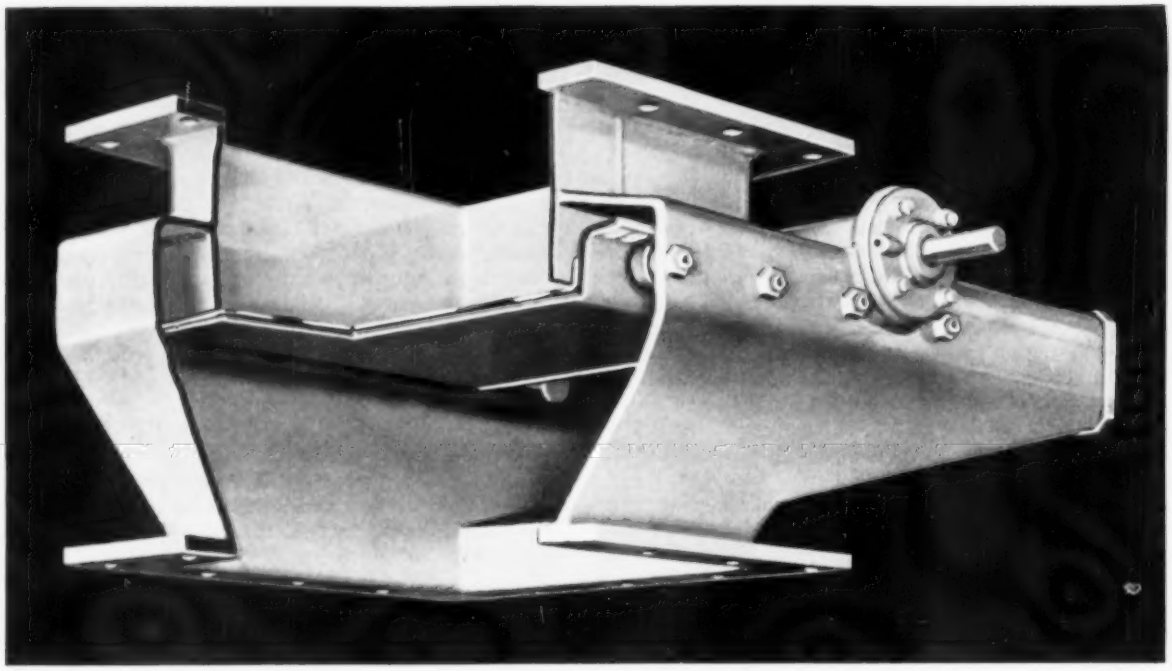
In spite of an increase in domestic demand and a general improvement in inventories, the year as a whole was not a particularly good one, Porter said.

In addition, widespread disagreements over imports of foreign oil added to the difficulties of the domestic picture, Porter went on. He noted that in mid-December, after months of debate, the issue of voluntary versus mandatory controls still was unresolved, with little hope that either proponents or opponents would be happy with whatever proposal is evolved.

Surpluses of oil that harassed the industry during the first five months of the year were, for the most part, worked off so that by December crude stocks actually were down from the 1958 peak. Refined products went up somewhat but total stocks reflected the decrease.

This was not done without cost, however. Production of domestic crude sagged for the second straight year. Refinery runs were trimmed materially even though operable capacity climbed to an all-time high. Drilling operations were curtailed, and many rigs were stacked over a large part of the year. Well completions were off sharply, for the second year in a row, and footage drilled plummeted to a five-year low. Exploratory drilling—so vital to future supplies of oil—also declined.

Motor fuel supply and demand were about even-Stephen at year's end, although consumption was up about 1½ per cent over 1957's record level. A bright spot for consumers was that octane levels for regular and premium gasolines showed continued improvement, in spite of industry difficulties and resultant higher costs. Since 1941, the octane level of regular gasoline has climbed from 80.1 to 89.8, while premium rose from 86.8 to 97.6.



Here's The Inside Story On The New

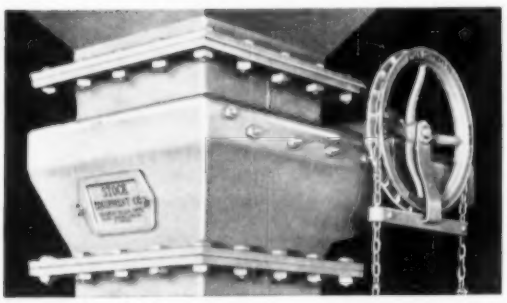
S-E-CO. Coal Valve

Strip the ⅜" steel skin off our new coal valve and you'll quickly see why *you get more when you buy S-E-Co.*

First, notice the deep U-shaped gate, which completely shields rollers, racks and pinions from coal flow. See how the gate provides lap closure on all four sides assuring positive cut-off. Also, note the stainless steel liner on top side of the gate to combat corrosion.

Carefully formed ladder racks, for their part, are self-cleaning having no root portion in which coal dust can build up and cause jamming. The multi-faced pinions, located above the racks, are also of self-cleaning design. Consequently, the gate moves smoothly with little effort, even after long periods of not being operated.

Notice the clean interior design. Slopes have been kept at a maximum with shoulders and projections eliminated. Even the poke hole covers fit flush with the inside of the valve body so that nothing interferes with flow of coal through the valve.



For a complete list of all the outstanding features of the new S-E-Co. Coal Valve together with installation photographs and dimensions, write for Bulletin No. 97.

STOCK Equipment Company

745-C, HANNA BLDG., CLEVELAND 15 OHIO

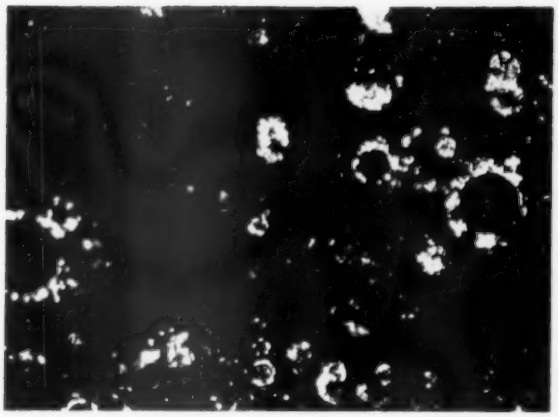


Fig. 1a—Superheater deposit (Thin section X 250 after H. Kirsch). Spheres of glassy slag encrusted by sulfates

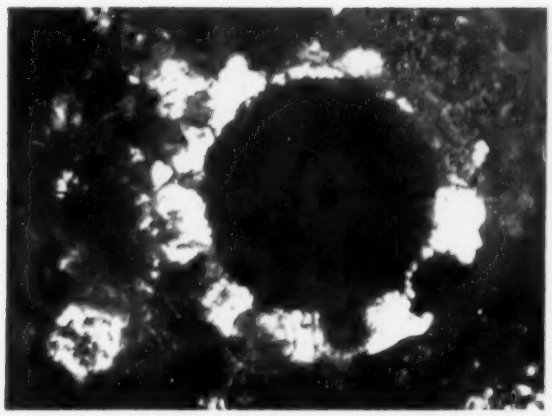


Fig. 1b—Single slag sphere (X 1000)

Investigations on Coal Minerals and Coal and Fuel-Oil Slags

A major concern of the Boiler Operators Association, Essen, Germany, is the problem of deposit formation and boiler availability. The author discusses recent developments and results of experiments carried out by Steinkohlenbergbauverein, Essen, a research organization of the Mining Industry, and its subsidiary research station, the Bergbau Forschungs- und Versuchsanstalt. The need for more research work both on a laboratory scale and in field experiments is strongly felt to reach a better understanding of the problems involved. Only by fundamental research can a practical solution be expected.

By WILHELM GUMZ

Dr.-Ing., F. Inst. F.

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THE importance of research in the field of boiler fuels and in particular of their mineral matter has been emphasized in a series of papers a few years ago (1).† Any study of this kind has to be based on the minerals in the coal, their behavior during the process of combustion and their effects on the heating surfaces or other surfaces, including the electrode plates of electrostatic precipitators.

The Need for Study

In most European countries, the need to increase boiler availability is felt more strongly than in the U. S. because of the firing of lower grades of coal. In Germany, for example, the preference for slagging furnaces has become another reason to spur research as a means to overcome a number of unexpectedly severe problems. The preponderance of slagging and cyclone furnaces, on the other hand, is a direct consequence of the necessity to get rid of fly ash with little or no possibility for storage or complete absorption into economic uses (2).

† Numbers in parentheses refer to similar numbers appearing in list of References at end of the article.

The only other alternative, the sintering of fly ash and its conversion into a useful raw material for the building industry, has received much interest and new developments are on their way. These solutions include the sintering on a traveling grate (the principle of the Dwight Lloyd sintering process), and the sintering in a shaft furnace. This may be accomplished in a separate plant such as the first installation on a commercial scale at the Battersea Power Station in London (Sinterlite Co., London) and a second commercial experiment initiated in the Netherlands (Losche K. G., Düsseldorf), or it may be in a close proximity to the boiler furnace itself as suggested by Paul (3). An economic solution of any of these processes will assist power station management in making decisions on the type of furnace to be selected.

The basic work on the roles of minerals in fuels initiated by the Vereinigung der Grosskesselbesitzer, Essen, and conducted in close cooperation with the research organization of the German coal-mining industry, is reflected in a recently published book which may be taken as a first progress report of a research program on fuel research planned to continue for many years (4). Another Interim Report has been read at the annual meeting of

VGB, Bremen 1958 (5). A characteristic of this type of research work may be the absence of sensational findings and the necessity of painstaking, slowly advancing work of a more fundamental nature. This work is aggravated by the complexity of the materials in question, the reactions involved, and by such factors as high temperature, effects of temperature gradients, and time. This rather recent branch of combustion research, however, has undoubtedly already contributed to a clearer picture of what is going on in a furnace, and the trend of development has been influenced by the conclusions reached. Empirical results, such as the effects and efficacy of fuel additives, have found a reasonable explanation (6), and the boiler designer has been directed to the true nature of his problems. Many questions still remain unanswered. It is mostly the destiny of research to give a few answers but to stir up a greater number of new questions. We must therefore face the fact that the step from empirical to scientific boiler operation and firing methods is a big one, supplying enough material for generations of research workers to come.

Organizing Studies

The starting-points of all studies concerning deposit formation, as already stated, are the minerals occurring in the fuel. The elementary analysis of a coal ash, for example, of a deposit, or of slag—useful as it may be—may allude to the minerals present, but it is by no means sufficient to recalculate it in terms of mineral species. The behavior of any type of matter, however, does not depend upon the elements present but to a high degree upon the structure of this matter. This is apparent and consequential in the case of the mineral matter in fuels, its reactions, and its final conversion into slags or other residual products of an entirely different structure.

Time is another factor which covers an extremely wide range. Speaking of ignition and combustion, especially of pulverized and liquid fuels, we think in terms of milliseconds or one to two seconds at the most, yet the residence time of slags and deposits may vary from hours to indefinite. Reaction of and within solids or liquids of high viscosity are usually very slow, taking days or weeks, and yet there is reaction, movement, migration—the whole system, highly disturbed in its equilibrium is in a perpetual change and should never be regarded as static.

Considering the many processes taking place inside a furnace, the material balance is only one side of the picture, and never the whole picture. In operating a furnace it becomes evident that the structural condition, the design of burners, the shape of the furnace, for example, and the operational condition, beginning with the allotment of right proportions of fuel and air to each burner, the complete and quick mixture of fuel and air, the velocities, the flow of gases, the transport of solid matter within the flue gases, and many others are decisive for the whole process. Slagging furnaces (including cyclone furnaces) may be considered as high-breed devices where any mistake in operation will have consequences which in a low-rated furnace will never show up. This is one of the many reasons why the behavior of mineral matter may have been considered as interesting but not very pressing, why empirical solutions and a few technological methods (such as the determination of fusing temperatures) seemed to be sufficient, as long as dry-bottom furnaces with combustion rates of 12,000 to 15,000 Btu/cu ft hr have been predominant. With the increase of burning rates to as high as 50 to 500,000 Btu/hr cu ft with combustion temperatures of 1700–1800 C and increased tube wall temperatures, a revision of viewpoints and methods has turned into a necessity and the solution of these problems is a must.

Deposit Formations

In considering the process of deposit formation we may raise three main questions:

(1) What kinds of material are the constituents of a deposit? Depending upon the range of temperatures where the sample was taken it will show a banded structure, with bands of various color and sometimes a variation of particle sizes.

(2) By what mechanism did the particles reach the surface and what made them stick to it and grow to sometimes considerable size and odd shapes?

(3) What kind of changes or reactions are going on in the interior of the deposit and what causes such reactions or migrations?

Just by visual inspection we may divide the various types of deposits into three groups:

(a) Molten slag, covering the wall (mostly studded tubes), deliberately produced at the wall of a slagging furnace

(b) Hard sintered deposits, sometimes fused at the outer surface, of a banded structure, the most common type of superheater deposits,

(c) More or less loose deposits without a banded structure, weakly caked and sometimes easily blown off, predominant in low-temperature regions.

The most interesting, or rather most annoying, type is the second one which has to be considered in some detail. The first one is caused by throwing the residual slag particles to the wall already covered with a viscous liquid slag (or with rammed refractory material at the beginning of furnace operation). The last one is simply deposited by action of the gas flow. The lee side of a tube will allow the flue dust to settle. The proper formation of hard deposits, however, cannot be explained by the throwing on of sticky slag particles or by the settling of ordinary fly ash.

The solid matter entrained with the flue gas emanating from a furnace comprises a variety of particles of a considerable size range, from coarse residual coke and glassy slag down to invisible sizes revealed by the electron-microscope and to possibly undetectable fineness. This ultrafine matter requires most of our attention because the study of the physical structure of deposits has shown that the first layer usually consists entirely of ultrafine matter, deposited selectively, and that larger particles in themselves are often covered by layers of very much smaller particles, thus altering the behavior of their surface entirely. Fig. 1a shows a thin section of a superheater deposit. The main constituents are spheres of glassy slag, surrounded by crusts of a sulfatic (soluble) material. The enlargement of one such sphere in Fig. 1b makes it even better visible how small particles have settled on the

surface—most likely already when this particle was still gasborne—and how they constitute some kind of a binder between adjacent particles of various—even large sizes.

Turning to the first question relating to the kind of materials, we have to bear in mind that the main constituents of the mineral matter (of bituminous coals at least) are clay minerals. Among the clay minerals the large group of illites (hydromuskovites) are frequently encountered in coal ashes. They provide the SiO_2 and Al_2O_3 as well as most of the alkalis, mainly the potassium. When heated to temperatures above 1000 C, the alkalies are released. At still higher temperatures, above 1550 C and in a reducing atmosphere, SiO_2 is volatilized presumably by formation of SiO which reoxidizes to SiO_2, visibly demonstrated as white fumes by earlier experiments (1, 4). Al_2O_3 likewise is evaporated, although the mechanism is not yet clear. However, the formation of a short-lived intermediate oxide perhaps of the monoxide-type (AlO) is most likely. The furnace tube of a high-alumina material used in these experiments stands only a limited number of runs because of its reaction with carbon. It has not been possible to catch and stabilize these intermediate combustion products, but their oxidation products (SiO_2, Al_2O_3) are visible and could be studied under the microscope and the electron microscope (see Fig. 2). These reactions presuppose an intimate contact of organic and mineral matter.

Such an intimate contact is given even in finely divided fuel such as pulverized coal. Clay minerals occur in particle sizes down to 100 Ångstrom, internal diameter, invisible fineness. In fact, particles of pure coal do not exist in reality; small impurities are always present besides particles of higher ash content (true middlings) and more or less pure mineral matter.

In addition to clay, the phosphorous minerals require special attention. It was found that phosphorite, a less throughly crystallized variety of apatite, is more frequent than apatite itself. In close contact with the coal substance, phosphorus is easily removed and oxidized into the pentoxide. Pyrites and hematites are the principal ferriferous minerals. The group of carbonic spars are readily broken up into the metallic oxides and carbon dioxide. Salts, finally, are another source of alkalis, mainly occurring as chlorides and in rarer cases as sulfates or others.

By the reactions taking place during combustion this mineral matter is released in some form or another, whereby a large quantity goes into a kind of glass with little time left for recrystallization. Some will turn into oxides, into monoxides in a vaporized form and into true vapors and gases (such as H_2O, CO_2, SO_2 etc.). All kinds of processes are possible: melting, reduction, oxidation, sublimation or just dust formation.

Slagging Furnaces

In slagging furnaces, other sources of gas-borne vapors are those emanating from the liquid slag film. By the work of Turner, Dietzel, and their co-workers (10) it is well known that alkalioxides, CaO, SiO_2, and other constituents of the glass could be evaporated. Since the slag stays in the furnace for a large span of time, this source of superfine matter in the flue gases certainly plays a decisive role in two ways—helpful to adsorb all of the SO_3 present and to suppress the acid dew-point of the flue gas; and less desirably to increase the formation of hard deposits within the superheater and sometimes layers of dust even at electrode plates in precipitators. These are difficult to remove and lower the efficiency of precipitation considerably.

The gas-borne solid matter is carried through the boiler flues. There are a number of theories to explain what kind of forces makes them touch the surfaces, penetrate the laminar boundary layer, and stick to the surfaces. The theory also should explain why a certain size range of roughly 2μ particle diameter or less preferentially forms the first layer although the penetration of the boundary layer presupposes a much larger particle size of about 20μ or more. According to Rumpf (7) the smallest particles agglomerate to larger units which are accelerated by the traverse forces of the turbulent motion and disintegrated into their constituents which he calls the "snow-ball effect." Other forces to be mentioned are thermodiffusion which primarily affects the smallest particles of 0.1 to 0.3μ diameter and electrostatic forces which in a cloud of pulverized coal can reach an unexpectedly high tension. Voltages of 2000 3000 v have been measured in some cases. The forces keeping the particle at the surface (apart from the merely mechanical entrapment of particles by rough and oxidized metal surfaces, as shown earlier (1)) depend very much upon the size and nature of the particles in question. Somewhat larger particles

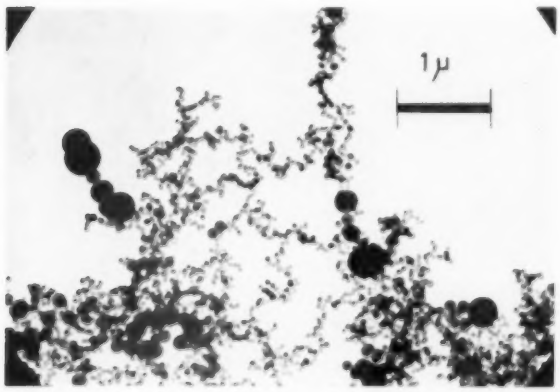

Fig. 2a—SiO_2 spheres produced by reoxidation of SiO (el. micr. × 12,700) after Th. Nemetschek

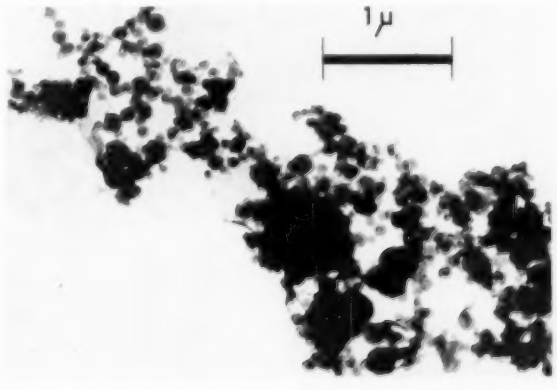

Fig 2b—SiO_2 spheres and silicon mist appears in the deposit of a fouled superheater

Fig. 3—Diffusion of alkali compounds from slag spheres, heated to 720° C for 2½ hrs. After Th. Nemetschek (el. micr. × 8,000)

which would not adhere by their own surface qualities are often already covered by other materials or may be covered by simultaneous settlement of larger and superfine dispersed matter of aerosol character. These precipitations may be alkali-oxyds, CaO, MgO, as well as oxidation products such as SiO_2, Al_2O_3, Fe_2O_3. If the temperature is low enough to allow their existence, sulfates and phosphates are formed by the adsorption of SO_3 and P_2O_5. The extremely small size of such sublimation products and the low fusion temperature of the various complex compounds assist the adhesion and the build-up of layers which readily increase the surface temperature and help to accelerate the process more and more. High alkaline content, as in salty coals, or a high release of alkalis from clay minerals or other sources by extremely high temperatures, may produce a troublesome deposit within hours which would take weeks or months under more usual conditions.

As soon as a certain depth of the layer is reached and a temperature gradient within the layer is developed, the migration sets in, and reactions occur with increased velocity. The formation of a banded structure has only been observed in certain temperature ranges—especially those occurring in the upper part of the combustion chamber and in superheaters, but not at lower temperatures such as the second pass of the boiler, economizer or air preheater. It appears to be the result of a migration rather than a subsequent settlement of various types of materials. The red or brown appearance of deposits is caused by iron which is taken to a great extent from the tube material. At the tube surfaces a white layer of sulfates, phosphates and siliceous material will accumulate. If there is no temperature difference—as for example, on an uncooled superheater hanger—no such enrichment of alkalis has been found (8, 9). The beginning of reactions within slag particles has been observed by Nemetschek (11) under the electron microscope. By heating spheres of glassy slag at 670 C (1238 F) for several hours nothing happened; at 750 C (1382 F) under vacuum, edged particles were protruding from the smooth spheres after 2½ hours of treatment. They were water soluble and are believed to be alkalis. This temperature is just in the range of surface temperatures of superheater deposits, and such materials may contribute greatly to the formation of hard scales.

Corrosion Problems

As has been mentioned, studies on deposit formation and of reactions taking place within deposits are of increasing interest because of a growing number of cases of corrosion. It is well understood that combustion conditions, maximum combustion temperature, the intensity of heat flow to the wall and of the cooling at the inside of the tubes, and finally the atmosphere surrounding the tubes or their deposits are main factors determining the rate of corrosion.

Corrosion problems are of even greater interest in the case of fuel-oil firing. A mineralogical study of the nature of oil slags by Kirsch and others (12, 13, 14) has shown that the composition of deposits in oil-fired plants displays a maximum of V_2O_5 in the temperature range of the superheater. The microscopic examination reveals needlelike crystals and some twin crystals of the compound $Na_20.6\ V_2O_5$; also $NaVO_3$(sodiummetavanadate) has been found. In an aqueous extract, which proved to be of a high acidity, iron sulfate has been identified, the iron having been taken from the tube material.

The maximum superheater temperature is limited by the corrosive action of oil-slag deposits. Fuel additives are required to change the nature of deposits and to counteract the corrosive attack of sodium-vanadium compounds. Since the course of the sintering process and the physical structure of deposits is of great influence, Kirsch and Pruss have started a study of the inner surface of the various mixtures of additives and vanadiumoxides as well as the corrosion products and V_2O_5. The BET-method has been used. Although of a merely theoretical interest, it has been demonstrated that Chrysatile—a fibrous serpentine with a large inner surface of 25 m^2/g which is maintained even at temperatures up to 1000 C (> 1800 F)—is able to adsorb a large amount of V_2O_5. However, these experimental data show the importance of the structural nature of additives as well as their composition. These studies will have to be continued before final conclusions could be drawn from them.

From a more practical point of view, the result of many of these studies have lead to a much better assessment of the various factors affecting the operation of a boiler furnace. Progress in the field of steam cycles must be accompanied by progress and better understanding of fuel firing processes. Future work will stress the study of re-

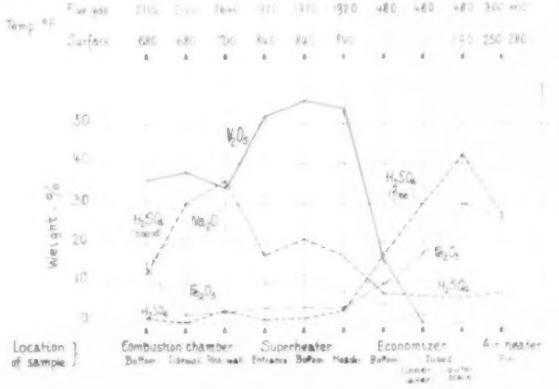

Fig. 4—Analyses of fuel-oil slags (weight-%). Absc. Location of sample. Flue gas and wall temperatures see upper run of graph (after H. Kirsch and W. Pruss)

actions within deposits, corrosion and means to prevent corrosion. In any case the solution requires a multiplicity of scientific knowledge which reflects the complexity of the problems involved. An exchange of ideas on an international basis will certainly be as fruitful in this field as it has proved to be in other fields.

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Engineers Evaluate Russian Engineering Education

Engineering education of sound quality is effectively integrated into the planned economy of the U.S.S.R.

This was one of the major observations of the eight-man mission of U. S. engineering educators who returned this week from three weeks of study and inspection in the U.S.S.R.

Among their observations, members of the mission called attention to the dynamic character of Russian engineering education, the continuous process of re-evaluation affecting it, and the ability of this controlled system to adjust to the inevitable variations in personal capabilities at both the student and faculty level.

The mission was sponsored by the American Society for Engineering Education and the National Science Foundation with the cooperation of Engineers Council for Professional Development. Its chairman was Dr. Frederick C. Lindvall, chairman of the Division of Engineering at California Institute of Technology; Professor Newman A. Hall, head of the Department of Mechanical Engineering at Yale University, was secretary.

Other members were:

William T. Alexander, Dean of Engineering at Northeastern University, Boston, president of the American Society for Engineering Education.

Dr. William L. Everitt, Dean of Engineering at the University of Illinois, president of Engineers Council for Professional Development.

Professor Ralph E. Fadum, head of the Department of Civil Engineering at North Carolina State College.

Dr. Albert G. Guy, professor of metallurgical engineering at Purdue University.

Dr. Ralph A. Morgen, director of the Purdue Research Foundation.

Dr. Leon Trilling, associate professor of aeronautical engineering at the Massachusetts Institute of Technology.

This mission was initiated by the Department of State under an agreement with the U.S.S.R. for the exchange of scientific and cultural delegations. A comparable Soviet educational mission is expected to visit the United States in February, 1959.

Members of the U. S. delegation visited 25 teaching and research institutions in Moscow, Leningrad, Kuibyshev and Frunze. The last is the capital of the Kirgiz Soviet Socialist Republic, situated on the border of China some 2100 miles southeast of Moscow. This city was of particular interest because its engineering school is new, growing rapidly and planned to meet the particular needs of an expanding industrial and agricultural economy.

A long-range plan covering a period normally of five years (currently seven years) is formulated first. Each year this master plan is modified to take into account the accomplishments actually achieved in the previous year.

The seven-year plan now being formulated contemplates that an average of 350,000 graduates in all professional fields (engineering, science, medicine, languages, etc.) will complete their training each year. This is an increase of 40 per cent over the average of the past seven years, but in engineering it is proposed that the increase shall be 90 per cent.

The master plan specifies:

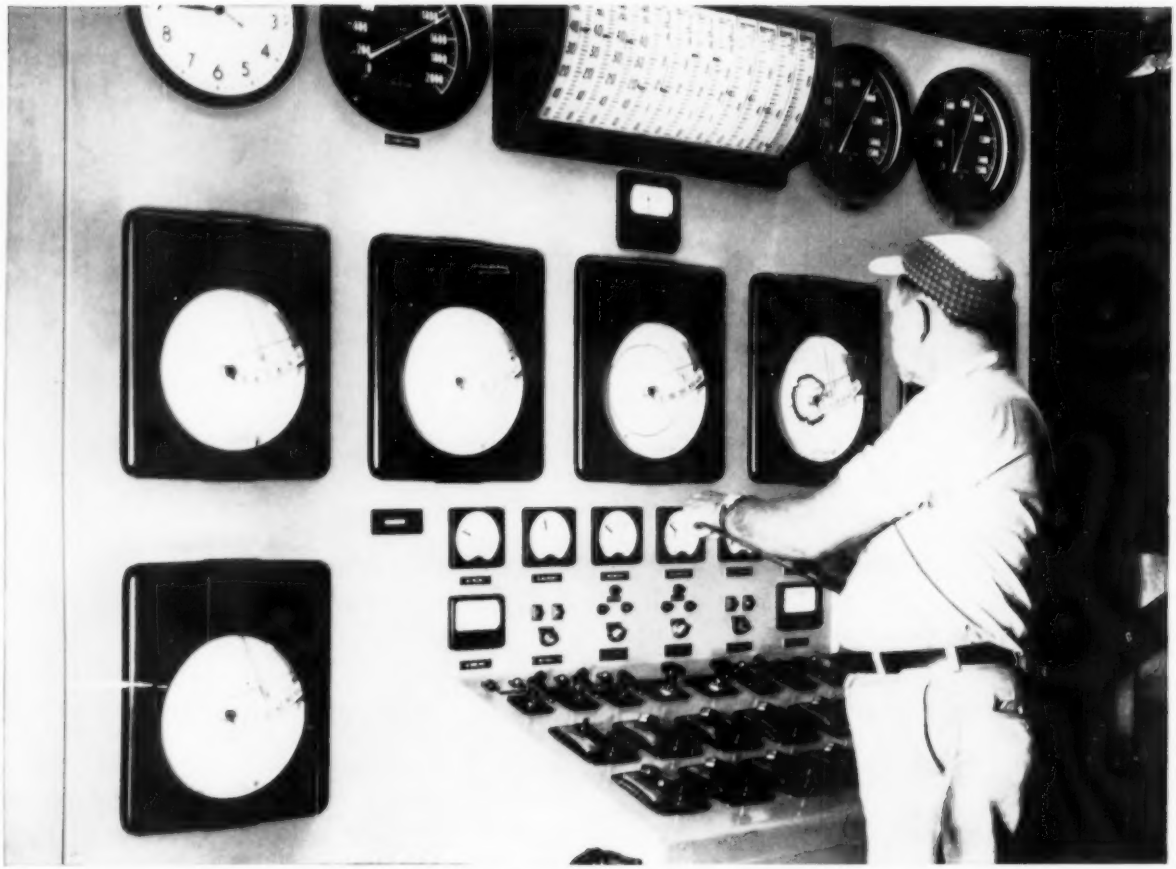
(a) the number who may enter the institutions of higher education,

(b) the number who may train for each field of specialization,

(c) the quota of each specific institution for each speciality,

(d) the jobs which will be available at the time of graduation.

Such planning demands that each student (at present upon graduation from the ten-year school at the age of 17 or 18) must choose irrevocably a narrow field of specialization when he applies for admission to college. Alternatively, he may postpone this decision by temporarily entering industry; under changes now contemplated, this period of industrial experience may become obligatory. The rules allow the student to apply for only one field of specialization in one institute in a given year. Furthermore, he commits himself to work in the particular phase of industry for which the course is designed. If he fails to secure admission in competition he may not apply for higher education for a year.



Control Room for Cyclone Furnace Boiler at Mathews No. 2 Power Plant of Greenwood Mills, Greenwood, S. C. Bailey MINI-LINE System concentrates controls at operator's station.

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The increasing use of incinerators as a means of disposing of both municipal and industrial refuse or waste materials, combined with increasingly high fuel and power costs, poses the question as to how much heat is available from such a furnace, and can it be utilized advantageously.

By H. G. MEISSNER, P.E.
Combustion Engineering, Inc.

Heat from Incineration- Available Quantities and Utilization*

THE problem of determining the heat output from an incinerator is easier to solve when the characteristics of the material to be burned are known and understood. In the case of municipal refuse for example, the percentage of high moisture garbage has declined, in many localities, from the former 65 per cent or more, to 10 per cent or less, with the advent of prepared, frozen, canned and otherwise packaged foods, as well as the use of kitchen sink garbage grinders and similar systems in both homes and restaurants. The current rubbish therefore includes large amounts of paper, bags, cartons, crates and similar dry, combustible material, much bulkier but more easily burned, provided the furnaces are adequately designed, which requirement has been too often overlooked in the past. Table I includes heating values of the ingredients usually present in municipal refuse.

The character of industrial refuse has also changed quite radically during the past decade, with the greatly increased output of plastics and other synthetic materials, many of which have much higher unit heating values, with little moisture or ash to burden them in the furnace. The list Table II shows the Btu per lb for some industrial waste products which have been offered for disposal by incineration, partly because of more stringent air pollution laws which prohibit the former open dump method, and partly to reduce hauling costs.

* Presented at the American Society of Mechanical Engineers Annual meeting, Dec. 1-6, 1958, New York, N. Y.

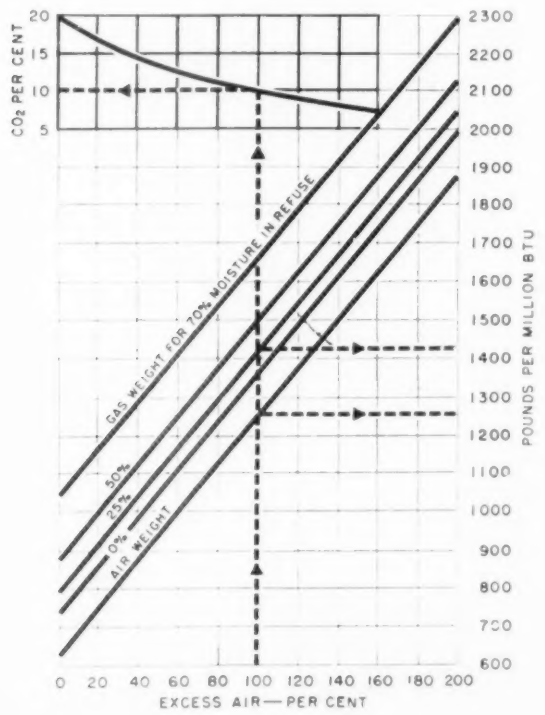

Fig. 1—Combustion products-air and gas weights per million Btu

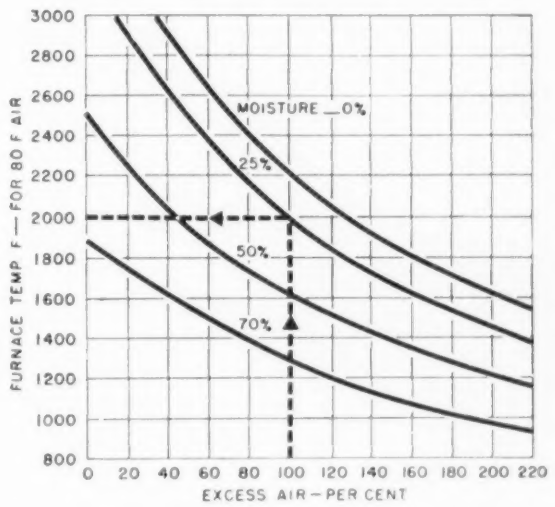

Fig. 2—Furnace temperature for various excess air and moisture contents

While highly variable in appearance, the combustible portion of municipal refuse is quite uniform in chemical analyses, being so closely related to wood and similar cellulose raw materials, from which much of it is derived. A large Western university reports as follows on the fuel value of municipal refuse. "Analyses made of samples of the refuse burned during the tests showed that the heat of combustion on a moisture and ash free basis was very close to that of cellulose, or 8000 Btu per lb, regardless of the chemical combustion of the fuel. This fact simplified the calculations of the heat process, and made it possible to predict the behavior of the material when it was burned. The most important variable was the moisture in the refuse, which is considered as the burden, or the energy consuming load of the incinerator."

When we try to evaluate the heat content of refuse we may find wide variations in moisture, ash and other ingredients in samples from various parts of the country, depending largely on collection procedures, climate and eating habits. Fortunately, however, no one incinerator has to be designed to handle such a wide variety, as it is concerned only with the refuse delivered from its immediate neighborhood.

Allowances must, of course, be made for possible changes in this neighborhood, such as from residential to industrial, but such changes generally occur over a prolonged period, so that the operators can become trained and if necessary modifications can be made in the original design. With the proper furnace and facilities for storing and mixing the varied types of refuse as noted elsewhere, the effects of such changes can be greatly lessened. This follows the procedure of power plant engineers, who frequently design modern boilers so that they can be switched from oil to coal or other solid combustible as the market dictates.

The mechanical or combustion engineer with such special training in fuel technology and the design of furnaces, as well as mechanical handling equipment, instruments and controls, should therefore be especially well qualified to work closely with the sanitary and civil engineers, so as to assure the greatest efficiency and economy in the incinerator plant design.

Available Heat from Refuse Incineration

To determine the heat available from either municipal or industrial refuse, we must first determine or assume a unit heat value in Btu per lb, from a list such as that shown in Tables I or II or by calorimeter tests. This unit heat value is then converted into total heat produced in the furnace, on an hourly basis, which is preferably expressed as so many million (1,000,000 or 10^6) Btu, and is simply the product of the fuel burned in lbs per hour times the unit heating value, as fired.

TABLE I—TYPICAL MUNICIPAL REFUSE

Refuse	Btu/lb Moisture Free	Approximate Moisture Content, %	Refuse	Btu/lb Moisture Free	Approximate Moisture Content, %
Paper	7,900	3–10	Rubber	12,420	—
Wood	8,420	7–18	Leather	9,000–10,000	—
Garbage	7,280	75–90	Cellophane	10,000–12,000	—
Brush	8,600	17–65	Plastic	10,000–12,000	—
Leaves	7,000	30–80	Paraffin	16,803	—
Grass	7,640	50–60	Rags, cotton	7,165	10–12
Greenstuff	6,870	50–55	Rags, linen	7,132	10–12
Greens	8,135	50–55	Tire cord	12,000	—
Waxpaper	10,000–12,000	—			

As an example, let us assume a typical municipal refuse having a moisture-and-ash-free heat value of 8000 Btu per lb, with 25 per cent moisture and 12.5 per cent ash or other non-combustible, such as cans, bottles and tramp iron. The as-fired heat value is then 8000X (1-0.375) which equals 5000 Btu per lb. For a 100-ton-per-day (24-hour) rated capacity incinerator, we first convert this to 8340 lbs per hour, which we multiply by 5000 to arrive at a total of 41,700,000 Btu per hour (or 41.7×10^6 Btu for convenience).

The air required to burn this refuse has been determined by the above report as well as by calculations as five lbs per lb of combustible or 625 lbs per 1,000,000 Btu fired. From this base we can make a chart such as Fig. 1 which shows the air and gas weights for varying percentages or excess air and of moisture in the refuse.

As the average incinerator comprises an all-refractory furnace, with no water cooling to absorb the heat, it is necessary that we determine what furnace temperatures will be developed, and limit them to a safe value to avoid excessive slagging and maintenance. The curves in Fig. 2 are based on such calculations, and show the variations in temperature with moisture content and excess air. As we cannot always control the moisture, the furnace temperature must be limited by adjustment in the excess air supply, as shown by the dotted line, which indicates that for a 25 per cent moisture refuse we will need 100 per cent excess air, while for a 50 per cent moisture fuel, the excess air should be reduced to about 45 per cent. Using the values from this chart we find that the total air required will be 52,200 lbs per hour or 12,300 cfm, and the gas leaving the furnace will be 59,400 lbs per hour, or 60,300 cfm at 2000 F.

Straight Incineration

When this gas is to pass directly to the stack, through combustion, expansion or settling chambers, these cham-

TABLE II—TYPICAL INDUSTRIAL REFUSE

Solid Plant Refuse	Btu/lb Moisture Free
Latex coagulum	19,900
Gum scrap	19,700
Bus tires	18,000
Rubber scorched scrap	19,700
Reclaim trench cleaning	8,000
Labl chemical waste	8,000
Polyvinyl chloride	17,500
Vinyl scrap	17,500
Fuel cell cutting scrap	11,970
Tire Cord	12,000
Cut up shoes	8,500

Liquid Chemical Refuse	Btu/lb Moisture Free
Solvent naphtha	18,500
Carbon disulphite	8,000
Benzine	10,000
Latex waste	12,000
Coagulum waste	12,000
Oil waste	18,000
Fuel oil residue	18,000
Poly ethylene	19,840
Counter stock	8,500
Sponge inside	8,340
Calander scrap	8,220
Cork scrap	12,400
Boot & shoe trim	8,500
Butyl soles	11,500
Sponge waffle	8,500
Sponge scrap	8,500
Wind lace	8,500
Cement wet scrap	11,500
Aldehyde sludge	18,150

Combustible refuse	Avg 8000 Btu/lb Moisture Free
Cardboard	"
Paper & paper bags	"
Wood	"
Filter cloth	"
Plastic drum liners	"
Floor sweeping	"
Cafeteria garbage	"
Stitching room scrap	"
Non Combustible trash	"
Glass	"
Metal containers	"
Pipe & metal scrap	"
Silica material	"
	"
	"
	"
	"

Fig. 3—Recent incinerator equipped with dust collectors and short stacks

bers, as well as the stack, must be designed to handle gas temperatures of 2000 F or more as there is little cooling except for radiation and air leakage, between the furnace and stack. The stack for such an installation must usually be of double-lined refractory construction, between 150 and 200 feet high, the draft from which is usually excessive for the furnace requirements. In such cases water-cooled dampers are sometimes used, but a barometric type of damper may be preferable, as such a damper is outside the high temperature zone and less costly in construction and maintenance.

In the furnace, it is now possible to control the air supply and furnace draft so as to level out the heat output to a very great extent as noted above. Several recent installations are being provided to accomplish this automatically, which may be desirable even when the heat output is not utilized, as we will discuss further.

Fly Ash Control

Stricter air pollution ordinances may eventually cause replacement of the canventional expansion and settling chambers in favor of mechanical dust collectors or scrubbers, with induced draft fans and short stacks replacing the large brick chimneys which are now the symbol of municipal incineration. The neat appearance of this modern design is shown in Fig. 3. Such mechanical equipment functions best under reasonably steady conditions of temperature and volume. The well-designed plant should therefore control the primary combustion and subsequent gas cooling medium so that maximum collection efficiency will be assured at all times.

In the case of the wet scrubber, the dust removal begins as the gas enters the scrubber throat, by sprays at right angles to the gas stream. The gas is then further cooled and washed free of most of its entrained dust by sprays and baffles so that it leaves the scrubber outlet at about 150 F, which is much too low a temperature for natural draft, for which reason an induced draft fan is required. The stack for such a fly ash removal system need be only high enough to let the fumes and vapor clear the adjacent buildings. Water requirement for such a scrubber is approximately 2 gpm per million Btu burned.

About two thirds of this water may be reclaimed in dewatering tanks and recirculated, the solid deposits being removed by clam shell bucket or similar means. A typical scrubber installation is shown in Fig. 4.

When dry collectors of the multicyclone or similar type are used, as in standard power plant practice, the hot, dust-laden gas leaving the furnace must first be cooled down to about 700 F to prevent damage to the dust collector and I.D. fan assembly. This may be accomplished by means of air or water admission to the hot gas stream or a combination of same, as is done in the most modern incinerator plants. Quantities involved are shown in Fig. 5. In this connection it must be remembered that a pound of air heated from an ambient of 80 F to 700 F ab-

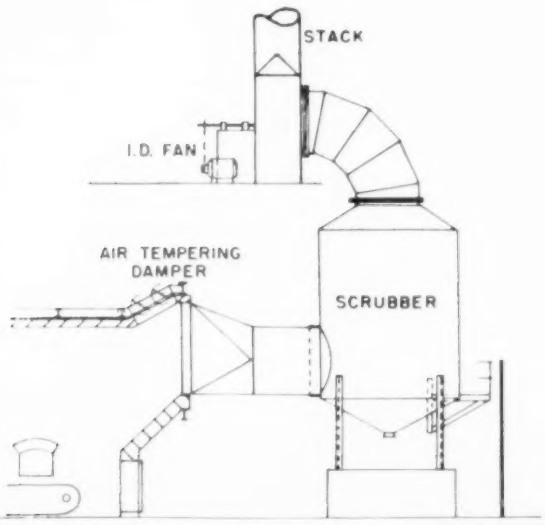

Fig. 4—Typical gas scrubber applied to incinerator furnace

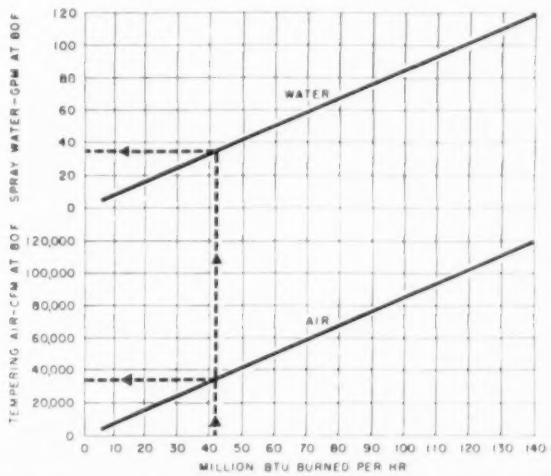

Fig. 5—Water and air required for cooling gas for dry dust collector installation

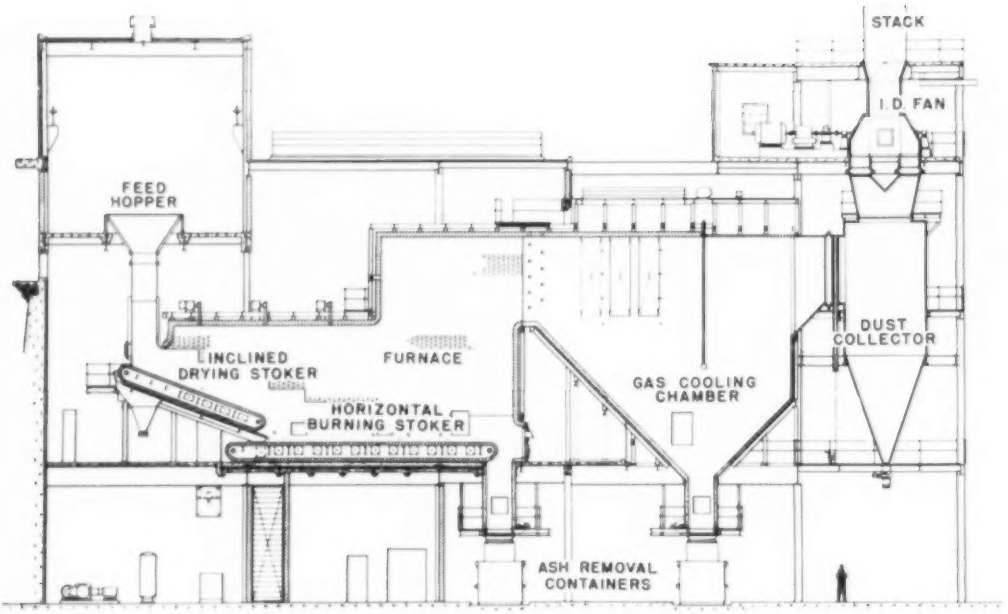

Fig. 6—Typical dry dust collector applied to incinerator furnace

sorbs 150 Btu, while a pound of water heated through the same temperature range will remove 1340 Btu from the hot gas stream. We must therefore use 9 times the weight of air as compared with water, which will affect the I.D. fan size and power requirement. Such an installation is Fig. 6. The sprays used should be of the fog-nozzle rather than the jet type, as the water must all be converted to dry superheated steam to avoid deposit of moisture and fouling of the dust collector elements, and minimize the water consumption. We still have much to learn regarding the elimination of stack effluent or fly ash.

Heat Utilization

The heat output from a modern continuous feed incinerator furnace is so much more uniform than that from the conventional batch feed types as noted above that utilization of this heat may prove profitable in many applications. Let us first consider more fully the available energy from various refuse materials, and then show possible means of putting this heat energy to work.

The heat value of common refuse materials may vary widely as shown in Tables I & II, depending on whether it comes from municipal or industrial sources. It may also vary in heating value from day to day, and from hour to hour, although these variations for a particular plant are much less than many of us realize. The highly differing appearance has confused observers in the past, and they have blamed the changes in heat output or furnace conditions on the fuel, rather than on the furnace or firing methods.

When the furnaces are batch fed it is obviously impossible to prevent variations in heat output as they are alternately stuffed and starved, as was the case in the old hand-fired coal burning days, the passing of which some of us still remember without regret. So the refuse was blamed for the irregularities experienced. With the modern continuous-feed type stokers installed in well designed furnaces, and with up-to-date instrumentation and controls, these variations largely disappear.

For example, with the popular bin-and-crane storage and handling system for refuse, the crane operator moves around and mixes the wet and dry material, as it is dumped from the trucks, so that the effect of a rainy day, or a big load or high moisture fruit or vegetables, is less noticeable. The use of covered containers, and the almost universal trend today to covered trucks, also have had beneficial effects on the heating value of the refuse, as the moisture content is by far the principal factor in determining the as-fired heating value of many common refuse materials.

The utilization of the heat from an incinerator is generally practical only when it can be done nearby, and as available, unless an auxiliary fuel such as oil or gas is included. Most incinerators are in operation from 8 to 24 hours per day and five or six days per week, as collections are seldom made over the weekend, and storage facilities for an extended period are usually impractical because of the bulky nature of the refuse, which averages 300 to 350 lb per cu yd when in storage.

The use of a low pressure heating boiler for hot water and winter plant heating requires a small portion only of the hot gas, which is usually bypassed from the furnace to the boiler and back to the stack. Such a boiler may, of course, be kept in service for hot water during the summer, as this type of equipment requires little attention or maintenance.

The boiler equipment for high pressure steam generation to be sold to a public utility or other commercial user is generally of a higher design pressure, so that licensed operators are required whenever it is in service. The cost of this labor as well as the maintenance and amortization must be considered, in setting the price charged for the steam. In general such steam output

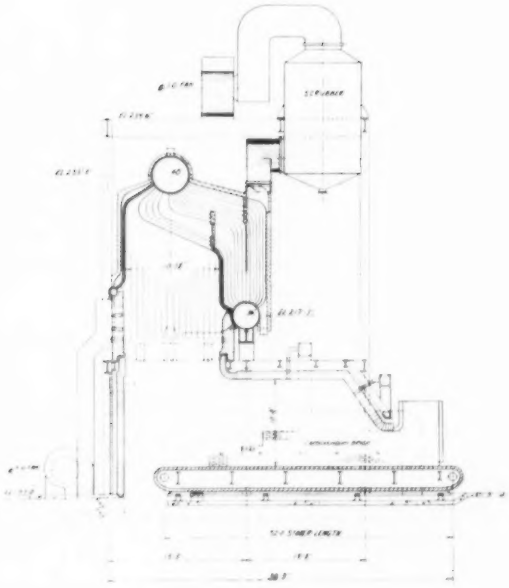

Fig. 7—Steam boiler fired by incinerator in industrial plant

must be at a relatively high and steady rate, to be attractive, and steam lines must be short to avoid undue losses.

The same considerations apply when power generation for sale is planned, only in this case the first cost and operating expenses will be proportionately higher, and the need for continuous, reliable service even greater.

Generation of power for the incinerator plant itself meets the requirement for proximity, and has been applied successfully in a few cases. The steam so generated can be used in back-pressure turbines so that the heat and hot water requirements are taken care of and the power output is used to supply all motors for fans, pumps, stoker drives and similar purposes. Provision may be made for supplying power or steam to adjacent municipal buildings or related uses, such as pumping water to storage tanks or other municipal requirements. With oil burners in reserve to fire the boilers, and a small diesel generator for start-up and emergency use, such a set-up becomes quite practical and economical.

When the incinerator is to be used in an industrial plant, the generation of steam or power becomes more practical, as it can frequently be located adjacent to the existing power plant, and feed whatever steam is produced into the plant headers. The regular operators can then take care of this additional unit with a minimum of cost, except for the refuse handling and storage facilities. The example below covers such an application.

The waste material in this plant comprised a number of liquid and solid combustibles from rubber goods manufacture, and a large chemical factory and laboratory, as well as a considerable amount of normal refuse such as garbage, rubbish, paper and wood products. There was also the usual complement of cans, bottles, metal scrap and ash or other inert material. The heat value of these ingredients ranged from 8000 to 20,000 Btu per pound.

A plant survey showed that this refuse totaled about 80 tons for an average day, and analyses on a weighted basis resulted in an average heating value of about

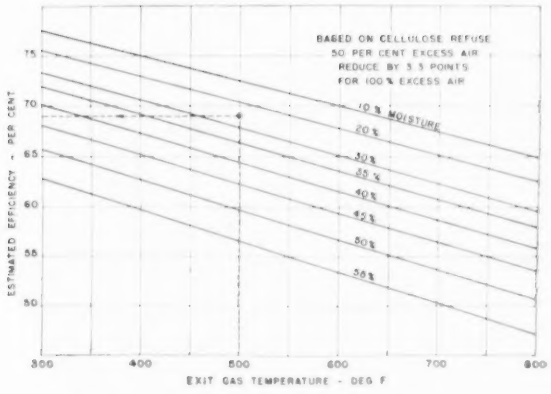

Fig. 8—Efficiency curves for boiler and incinerator

10,000 Btu, or a total of 1670×10^6 Btu per day. For the 24-hr operation proposed, the available heat output was 66.7×10^6 Btu per hr. Auxiliary fuel oil was provided for in the furnace design, which is illustrated in Fig. 7. The incinerator and boiler will be located next to the present boiler plant, with a bin-and-crane system for handling and storage. Mixing of the heterogeneous ingredients including solids and liquids will be accomplished here.

The overall boiler efficiency was estimated from Fig. 8 at 70 per cent, and the enthalpy of the steam was 1100 Btu per lb, so that the boiler output was easily calculated as 42,500 lbs per hr. If we take the efficiency when firing oil as 82 per cent, then each ton of refuse fired will replace 114 gal of fuel oil, and the 80 tons per day will save about 9140 gal of oil. Added advantages of this project include reduced hauling costs to the outside dump, and improved public relations.

For a close approximation we can predict an evaporation of 3 to $3^1/_2$ lbs of steam per lb of municipal refuse, or 6000 to 7000 lbs per ton, while for industrial wastes a somewhat higher evaporation may be possible depending on unit heating values.

The use of waterwalls in incinerator furnaces seems

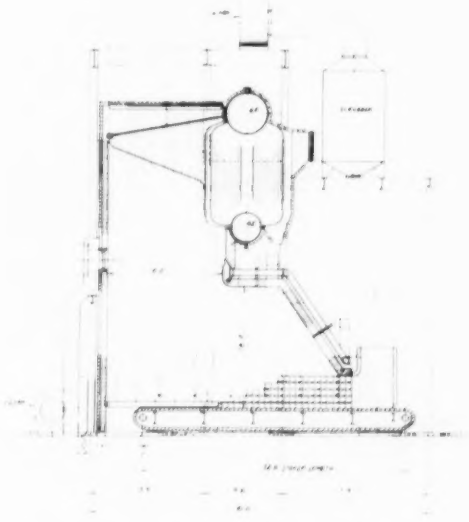

Fig. 9—Water walls applied to incinerator furnace

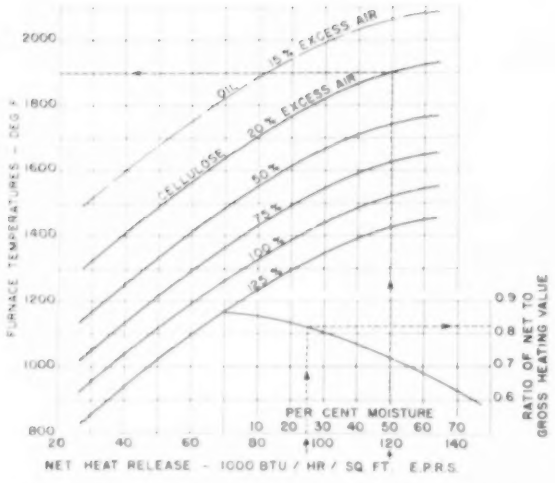

Fig. 10—Furnace temperatures in water wall incinerator furnace

justified only when a boiler is mounted above the furnace so that such heat absorbing surface can be tied into the steam generating cycle and become a major factor in the boiler output, as well as for refractory protection.

The actual combustion requirements of chemically similar fuels such as wood refuse and bagasse from cane sugar mills have been found by personal experience to be in the 10 to 20 per cent excess air range, when burned in waterwall furnaces. We may therefore safely assume that the normal run of refuse can be burned with not over 30 per cent excess air if the heat generated can be absorbed rather than radiated back from the furnace walls. This lower excess air and gas weight will then reduce materially the boiler draft loss and fan requirements, as well as the fly ash carryover. An example of such extended waterwall coverage is shown in Fig. 9.

The quantity of heat picked up in such a waterwall furnace is readily calculated, using the formulas and transfer rates developed by the boiler manufacturers after numerous tests. The black surface so installed is called "Effective Projected Radiant Surface," or EPRS for short and the curves shown in Fig. 10 are based on such tests, with the chemically similar fuels noted earlier. The resultant furnace temperature is obtained by dividing the total heat input from the combustion of the refuse, by the square feet of EPRS, and using the curve to read off the furnace temperature. The conversion scale from gross to net heating value is shown on this chart.

High temperature high pressure hot water boilers, which have become quite popular, fit in well as a means of utilizing the heat from incineration, provided that auxiliary fuel such as gas or oil is included to take care of weekends or other periods when suitable refuse is not available. Such controlled circulation boilers come in standardized capacities of 12,000,000 to 50,000,000 Btu per hr or more, corresponding to incinerator rated capacities of 30 to 120 tons per 24 hr.

This type of boiler is especially suitable for such applications as central heating plants for large buildings, shopping centers, military bases, all of which may have considerable refuse to burn, as well as for process heating for vulcanizing equipment, ovens or tanks with heating coils, calender rolls, heating platens, drying kilns, evaporators or similar industrial purposes in plants where there may be a surplus of combustible rubbish.

A typical application of an incinerator to fire a HTHW boiler is shown in Fig. 11.

The combination of refuse incinerator and sewage disposal plants seems to have increasing merit, as the hot gas from the furnace can be used in the flash dryers, and the sludge may be returned for incineration when it is not processed for fertilizer. Noxious gas may be passed into the hot furnace for dissociation of objectionable fumes before discharge to the atmosphere, thus reducing the height of stack required in many cases.

The illustration Fig. 12 shows a typical layout for such a combination of refuse incinerator and flash dryer, a number of which have already been purchased. This type of plant eliminates the need for auxiliary fuel, and assures absence of objectionable odor, and dust-free discharge of gas to the atmosphere. The incinerator furnace temperature of 1800 F or more assures complete reduction of any noxious odors, and the dust collector removes practically all the solids of fly ash from the stack discharge.

The dual disposal of mixed refuse and sewage sludge at the same plant site effects economies in both first cost and operating expenses, and enables the smaller communities to provide for modern disposal facilities, whereas they could not afford separate plants because of the added costs involved.

Gas turbines have been considered, to utilize the heat in the furnace gas through heat exchangers for the direct production of power, by either the open or closed cycle. This development is believed quite remote as there is still much research required to overcome the obvious problems encountered, such as high gas temperature and fly ash carryover.

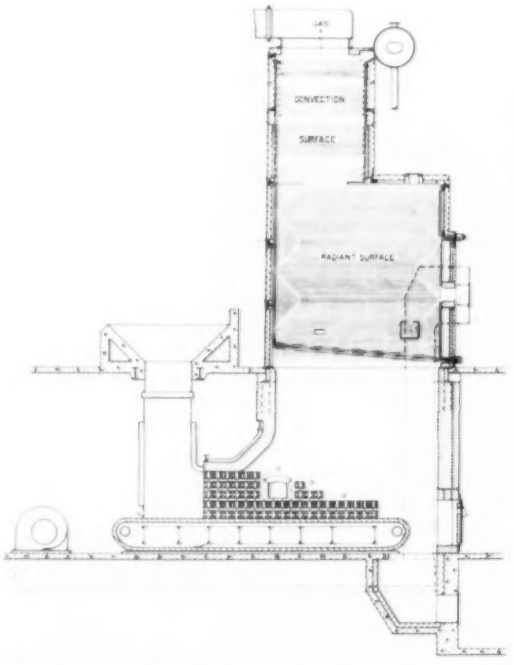

Fig. 11—High temperature hot water boiler fired by incinerator

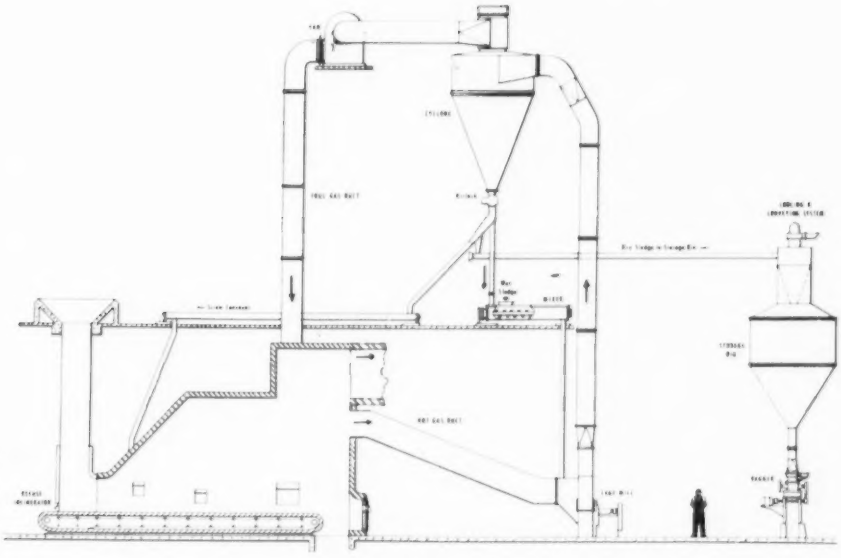

Fig. 12—Incinerator and flash dryer for sewage sludge disposal

Air heaters have been tried in some installations, but have been found unsatisfactory for several reasons. When the refuse is wet and hot air would be desirable, there is insufficient heat in the furnace gas to provide same. On the other hand when the refuse is dry and burns well the heated air tends to raise the furnace temperature unduly, so that more excess air must be used to counteract this increase.

The cost of such air heaters is quite high, as they must be made from expensive alloys to withstand the high gas temperature involved. If we assume a two thousand degree F gas temperature, and 500 deg F air preheat, then the metal temperature will be 1250 deg F, which is obviously too high for carbon steel elements. The continued use of air heaters seems therefore improbable, except when a boiler with water walls is included.

Conclusions

The time is rapidly approaching when we can no longer discharge hot, dust laden gas from an incinerator directly to the atmosphere. We will soon have to cool and clean it, or use it to generate steam or hot water, flash dry our sewage sludge, or otherwise make it harmless or useful.

The above discussion shows the quantities of heat involved, and some possible uses to which it can be put. Additional applications will probably become apparent as research in this field of engineering continues.

Forum Summarizes Progress in Nuclear Field During 1958

The United States during 1958 completed 37 nuclear reactors in this country and abroad, according to a year-end report issued today by the Atomic Industrial Forum, the national association of the U. S. atomic industry.

Highlighting the reactors completed were the atomic engines for the new atomic submarines *Swordfish* and *Sargo*, a dual-reactor land-based prototype of the U. S.'s first atomic power plant for a large naval surface vessel, a single-reactor land-based prototype for an advanced atomic submarine engine, and a ground-test experiment of a nuclear reactor designed for rocket propulsion.

Also completed during the year were a small, transportable reactor designed to produce both electric power and heat for remote Army bases, and two powerful test reactors in which atomic construction materials and fuels can be subjected to the rigorous temperature and irradiation conditions to be met in the nuclear power plants of the future.

The remaining reactors completed during the year include one small power experiment and 27 relatively small research and training devices.

The year 1958 also saw the U. S. begin construction on 45 reactors in the U. S. and abroad, including two reactors which will produce electric power for distribution to consumers in the states of Nebraska and Minnesota, a small reactor which will provide electricity and space heat for an Army post in Alaska, 13 reactors to propel submarines, an atomic engine for a naval destroyer and a land-based prototype for the destroyer engine, three large test reactors, and two small power experiment reactors.

U. S. industry also received new contracts during the year for the construction overseas of three reactors to produce electric power, including a large reactor to be built for the Italian government with financial assistance from the International Bank for Reconstruction and Development (World Bank) and two smaller reactors to be built in Cuba and West Germany.

Other highlights of the year include the completion of eight new U. S. uranium ore mills, the sale of at least 39 particle accelerators, new acquisition of large radiation sources by five industrial companies, award of a contract to build a major facility for the experimental preservation of food through irradiation and the completion of two new facilities for preparing nuclear reactor fuel.

Main steam, boiler feed and miscellaneous piping for the nation's first full-scale commercial atomic power plant.

Dravo piping at Shippingport

Fabricating and installing piping for the Shippingport nuclear power plant presented many unusual problems. Specifications were extremely demanding and new techniques had to be employed.

In Dravo's Marietta shops, more than 3700 welds were made on stainless steel, aluminum, and carbon steel piping, ranging in size from 3″ to 12″ diameter. Many more thousands of welds were made at the site and all were thoroughly inspected and tested to assure performance under exacting conditions.

Each of the piping systems was hydrostatically tested at 1½ times the operating pressures. All of the butt welds and 99.9% of the more than 11,000 socket welds were leakproof on the first test.

Fabricating and installing this piping for the nation's first full-scale commercial atomic power plant demonstrates Dravo's ability to handle piping projects of all types. A letter will bring full information on pipe fabrication and erection facilities—write Dravo Corporation, Pittsburgh 22, Pa.

View of the Shippingport Atomic Power Station which was built as a joint venture by the U. S. Atomic Energy Commission and the Duquesne Light Company. Westinghouse Electric Corporation developed the nuclear components of Shippingport under a contract with the AEC. Duquesne Light Company is operating the station. As a sub-contractor to Westinghouse, Dravo fabricated and installed more than 10 miles of piping at Shippingport.

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American Power Conference Program

THE twenty-first annual meeting of the American Power Conference will be held on March 31, April 1 and 2 at the Sherman Hotel in Chicago.

The Conference is sponsored by Illinois Institute of Technology in cooperation with fourteen leading universities and ten national and regional societies throughout the United States.

Tuesday, March 31, 1959 9:00 a.m. Registration; 10:00 a.m. 12:00 Noon. Opening Meeting

Chairman: Dudley Sanford, Executive Vice President, Union Electric Company, St. Louis, Mo.

Co-Chairman: W. A. Lewis, Professor of Electrical Engineering, Illinois Institute of Technology, Chicago, Ill.

a. Invocation. The Rev. William D. Faughnan, Chaplain, Illinois Institute of Technology, Chicago, Ill.
b. Education for Management in a Technological World. W. F. Rockwell, Jr., President, Rockwell Manufacturing Company, Pittsburgh, Penna.
c. Integration of Engineering and Financial Planning of Electric Power Systems. Murray Joslin, Vice President, Commonwealth Edison Company, Chicago, Ill.

12:15 P.M. Joint APC-ASME Luncheon. Sponsored by American Society of Mechanical Engineers

Chairman: Glenn B. Warren, President, American Society of Mechanical Engineers.

Co-Chairman: M. V. Maxwell, Chairman, Chicago Section, ASME.

Speaker: J. E. Corette, President, Edison Electric Institute and President and General Manager, The Montana Power Company, Butte, Mont.

2:00-5:00 p.m. Steam Turbines. Sponsored by Power Division of ASME.

Chairman: Vern Stone, Manager of Production, Commonwealth Edison Company, Chicago, Ill.

Co-Chairman: C. D. Campbell, Consulting Engineer, Westinghouse Electric Corporation, Philadelphia, Penna.

a. Ultrasonic Testing of Large Steam Turbine Parts. M. L. Smith, Tennessee Valley Authority, Knoxville, Tenn.
b. Progress in Steam Turbine Generator Research and Development. J. W. Stotts, Engineer-in-Charge, Generator Design, and J. K. Dixon, Engineer-in-Charge, Development in Engineering, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
c. Large Steam Turbine Generators for the 60's. E. H. Miller, Manager, Turbine Advance Engineering, and B. M. Cain, Large Steam Turbine Generator Department, General Electric Company, Schenectady, N. Y.
d. Advance Development in Component Design for Large Steam Turbines. R. Reese, Large Turbine Engineering Department, Westinghouse Electric Corporation, Philadelphia, Penna.

2:00-5:00 p.m. Water Technology I—Ion Exchange.

Chairman: L. F. Wirth, Jr., Manager, Ion Exchange Division, National Aluminate Corporation, Chicago, Ill.

Co-Chairman: J. W. Wilkes, Director of Research and Development, Dearborn Chemical Company, Chicago, Ill.

a. Two Bed Primary System Solves Mixed-Bed Demineralizer Problems. H. C. Farmer, Chief Chemist, Philadelphia Electric Company, Philadelphia, Penna.
b. Experience with an Improved Intermediate-Base Anion Exchange Water for Problem Waters. I. M. Abrams, Associate Technical Director, R. J. Cooley, Technical Representative, Eastern Area, and G. F. Stoneman, Manager, Ion Exchange Division, Chemical Process Company, Redwood City, Calif.
c. Filtration of Condensate as a Part of the High Rate Condensate Scavaging Process. W. H. Homer, Senior Process Engineer, and V. J. Calise, General Sales Manager, Graver Water Conditioning Company, New York, N. Y.
d. High Flow Rate Ion Exchange. Joe Thompson, Eastern Manager, New York City, and A. C. Reents, Research Director, Illinois Water Treatment Company, Rockford, Ill.

2:00-5:00 p.m. Fuels. Sponsored by Fuels Division of ASME.

Chairman: James R. Jones, Combustion Engineer, Peabody Coal Company, Chicago, Ill.

Co-Chairman: Edward M. Marselli, Plant Superintendent, Electric Energy, Inc., Joppa, Ill.

a. Evaluation of Coal Sampling Procedures. W. W. Anderson, Technical Director, Commercial Testing and Engineering Company, Chicago, Ill.
b. Producing Lightweight Aggregate from Molten Boiler Slag. Howard L. McNally, Senior Engineer, Dow Chemical Company, Midland, Mich.
c. Generating Station Coal Bunker Explosions. W. W. Hagnauer, Section Engineer, Mechanical Engineering Design Department, Commonwealth Edison Company, Chicago, Ill., and K. W. Hamming, Partner, Sargent & Lundy, Engineers, Chicago, Ill.

8:00-10:00 p.m. Long Range Goals For The Generation of Electric Power

Devoted to present thinking and future prospects for direct conversion of heat into electrical energy and for achieving electric power from fusion. Following presentation of papers, discussion and questions from the audience will be welcome.

Chairman: Andrew W. Kramer, Editor of *Atomics, Power Engineering*, Barrington, Ill.

Co-Chairman: Perry L. Blackshear, Jr., University of Minnesota, Minneapolis, Minn.

a. Direct Conversion of Heat to Electric Power—Its Present Status and Future Prospects. John C. R. Kelly, Jr., Manager, Technology Department, Westinghouse Research Laboratory, Pittsburgh, Penna.
b. Thermonuclear Fusion Research for Power. Leonard J. Linde, Manager, C. Stellarator Associates of Allis-Chalmers and Radio Corporation of America, Princeton, N. J.
c. Discussion.

Wednesday, April 1, 1959 9:00 a.m. 12:00 Noon. Symposium on Once Through Boiler Plants for Subcritical Pressure

Chairman: Ben G. Elliott, Chairman, Department of Mechanical Engineering, University of Wisconsin, Madison, Wis.

Co-Chairman: Reno C. King, Associate Professor of Mechanical Engineering, New York University, New York, N. Y.

a. Design and Operating Characteristics of Steam Generating Equipment. Elno Powell, Director of Research and Product Development, Combustion Engineering, Inc., New York, N. Y.
b. Operating Experiences at Portland Station. John G. Miller, Assistant Chief Engineer, Metropolitan Edison Company, New York, N. Y.
c. Operation and Water Conditioning at Unit No. 1 Tait Station. J. D. Williamson, Manager, Power Production, and R. F. Andres, Chief Chemical Engineer, Dayton Power and Light Company, Dayton, Ohio.
d. An Integrated Combustion Control System. E. D. Scutt, Head, Steam and Process Industrial Section, Market Development Division, Leeds & Northrup Company, Philadelphia, Penna.

9:00–10:30 a.m. Water Technology II—Analytical and Control

Chairman: S. F. Whirl, Chief Chemical Operating Engineer, Duquesne Light Company, Pittsburgh, Penna.

Co-Chairman: W. R. Homan, Chief Chemist, Commonwealth Edison Company, Chicago, Ill.

a. A New Method for Continuous Analysis of Dissolved Oxygen and Water. J. M. Wright, Fellow Engineer, and W. T. Lindsay, Jr., Supervisor Engineer, Bettis Atomic Power Division, Pittsburgh, Penna.

b. A New System for the Completely Automatic Chemical Analysis of Boiler and Condensate Waters in Power Plants. (Authors to be announced.)

10:30 a.m.–12:00 Noon. Water Technology III—Condenser Tubing Alloys

Chairman: T. J. Hodan, Sales Manager, Heat Transfer Department, Water Conditioning Products, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

Co-Chairman: (To be announced.)

a. Stainless Steel Condenser Tubes. Four Years' Experience. John C. Cokley, Jr., Product Manager, Alloy Tube Division, Carpenter Steel Company, Union, N. J.

b. Paper on Experience with Aluminum Condenser Tubes. (Author to be announced.)

12:15 p.m. APC-AIEE Luncheon Sponsored by the American Institute of Electrical Engineers

Chairman: R. B. Gear, Vice President, District No. 5, AIEE.

Co-Chairman: John A. Romano, Chairman, Chicago Section AIEE.

Speaker: Earl L. Butz, Dean of Agriculture, Purdue University, Lafayette, Ind. Subject: Research Gateway to the Future.

2:00–5:00 p.m. Central Station Power Plants

Chairman: H. L. Solberg, Assistant Dean of Engineering, Purdue University, Lafayette, Ind.

Co-Chairman: Francis Sevfarth, University of Illinois, Urbana, Ill.

a. The Second Year's Operation of a Supercritical Unit. T. T. Frankenberg, Division Head, A. G. Lloyd, Staff Engineer and E. B. Morris, Chemical Section Head, Mechanical Engineering Division, American Electric Power Service Corporation, New York, N. Y.

b. The Evaluation of Automation for Central Station Power Plants. F. A. Ritchings, Consulting Mechanical Engineer, and W. A. Summers, Mechanical Engineer, Ebasco Services, Inc., New York, N. Y.

c. Which Enclosure Shall It Be? C. D. Birget, Chief Mechanical Engineer, and J. H. Kline, Mechanical Design Engineer, Commonwealth Associates, Inc., Jackson, Mich.

2:00–5:00 p.m. Control of Generation on Interconnected Systems

Chairman: Nathan Cohn, Vice President for Technical Affairs, Leeds and Northrup Company, Philadelphia, Penna.

Co-Chairman: John J. Carey, University of Michigan, Ann Arbor, Mich.

a. Operating Experience with an Automatic Dispatching System. H. H. Mochon, Systems Operations Engineer, Connecticut Valley Power Exchange, Hartford, Conn.

b. Coordination of a Desired Generation Computer with Area-Wide Generation Control. N. E. Brown, Field Engineer, Los Angeles, Harry Fereshetian, Senior Project Engineer, Philadelphia, and M. D. Liechty, Field Engineer, San Francisco, Leeds and Northrup Company, Philadelphia, Penna.

c. Operating Experience with a Command Type Load Frequency Control System. W. D. Wilder, Superintendent of Power Control, Niagara Mohawk Power Corporation, Buffalo, N. Y.

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2:00–3:30 p.m. Water Technology IV

Chairman: M. D. Baker, Chairman, ASME, Joint Research Committee on Boiler Feedwater Studies and Chief Chemist, West Penn Power Company, Springdale, Penna.

Co-Chairman: Selden K. Adkins, Manager, Consulting Service, National Aluminate Corporation, Chicago, Ill.

a. Stress Corrosion of Stainless Steel and Boiler Water Treatment, Shippingport Atomic Power Station. W. J. Singley, Senior Engineer, Steam Generator Engineering, I. H. Wellinsky, Materials Application, Bettis Atomic Power Division, Westinghouse Electric Corporation, and S. F. Whirl, Chief Chemical Operating Engineer, Duquesne Light Company, Pittsburgh, Penna.

b. Discussion.

3:30–5:00 p.m. Water Technology V—Industrial Water

(Program to be announced.)

6:30 p.m. All Engineers Dinner

Presiding: Philip Sporn, President, American Electric Power Company, New York, N. Y.

Speaker: Herbert D. Vogel, Chairman of the Board, Tennessee Valley Authority, Knoxville, Tenn. Subject: Engineers Must Do Better.

Thursday, April 2, 1959. 9:00 a.m.–12:00 Noon. Steam Generators. Sponsored by the Power Division of ASME

Chairman: Alf Kolflat, Senior Partner, Sargent & Lundy, Engineers, Chicago, Ill.

Co-Chairman: T. S. Fetter, Executive Engineer, Engineering Department, Philadelphia Electric Company, Philadelphia, Penna.

a. An Operating Report of the Monitored Sterlington Station. Donald Aswell, Louisiana Power and Light Company, Westwego, La., and George Parmakian, Assistant Chief Mechanical Engineer, Riley Stoker Corp, Worcester, Mass.

b. Control System for Achieving Optimum Boiler Economy in a Single Unit Simultaneously Burning Three By-Product Fuels. W. O. Barnett, General Foreman Mechanical Operations, Utility Department, Fairless Works, Fairless Hills, Pa.

c. Gas Recirculation and Its Relation to Boiler Design and Operation. J. D. Andrews, Executive Engineer, A. M. Frendberg, Engineer Coordinator, and P. H. Koch, Manager, New Products Examination, Babcock and Wilcox Company, Barberton, Ohio.

d. Mechanics of Corrosion in High Temperature Superheater and Reheater Tubes. Edward M. Mar-

selli, Plant Superintendent, Electric Energy Corporation, Joppa, Ill., and Richard C. Ulmer, Manager of Research and Development, Combustion Engineering, Inc., New York, N. Y.

9:00 a.m.–12:00 Noon. Industrial Plants I

Chairman: (To be announced.)
Co-Chairman: A. D. Holland, Professor of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Ga.

a. An Industry Viewpoint. R. W. Precious, Union Carbide Olefins Company, South Charleston, W. Va.
b. An Industry Viewpoint. R. H. Emery, St. Regis Paper Company, Jacksonville, Fla.
c. A Turbine Manufacturer's Viewpoint. C. M. E. Ferson, General Electric Company, West Lynn, Mass.
d. A Boiler Manufacturer's Viewpoint. C. E. Miller, Combustion Engineering, Inc., New York, N. Y.
e. A Consulting Engineer's Viewpoint. J. A. Donald, Sargent & Lundy, Engineers, Chicago, Ill.

9:00-10:30 a.m. Peaking Service.

Chairman: T. E. Culwan, Assistant Superintendent of Generating Plants, Union Electric Company, St. Louis, Mo.
Co-Chairman: Severin Ravnor, Professor of Mechanical Engineering, Northwestern University, Evanston, Ill.

a. Automatic Plants for Peaking. Eugene W. Kettering, Engineering Consultant, B. B. Brownell, Chief Engineer, and B. H. Hefner, Chief Electrical Engineer, Electromotive Division, General Motors Corporation, LaGrange, Ill.
b. Design Concepts of a Low Cost Gas Turbine Generating Plant for Peak Load Service. A. O. White, Engineer, Gas Turbine Engineering Department, General Electric Company, and R. J. Carpenter, Engineer, Construction Engineering Department, General Electric Company, Schenectady, N. Y.

10:30 a.m.–12:00 Noon. Nuclear Power Plants I.

Chairman: Roy M. Casper, General Manager, Nuclear Power Division, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
Co-Chairman: Alan H. Stenning, Department of Nuclear Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

a. Power Reactor Safeguards. Robert H. Shannon, Director, Nuclear Power Development Division, United Engineers and Constructors, Incorporated, Philadelphia, Penna.

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b. A Design Code for Power Reactors. David B. Singer, Armour Research Foundation, Chicago, Ill.

2:00-5:00 p.m. Nuclear Power Plants II.

Chairman: Bernard I. Spinrad, Division Director, Reactor Engineering Division, Argonne National Laboratory, Lemont, Ill.

Co-Chairman: (To be announced.)

a. Pebble Bed Reactor. S. T. Robinson, Principal Engineer, and R. F. Benenati, Nuclear Consultant, Special Projects Division, Sanderson and Porter, New York, N. Y.

b. Industrial Development of Boiling Water Reactors for the Generation of Competitive Nuclear Power. R. B. Richards, Atomic Power Equipment Department, General Electric Company, San Jose, Calif.

c. A 150 MW Organic Moderated Reactor Power Plant. Ralph Balent, General Engineering Group, Atomics International, Canoga Park, Calif.

2:00-5:00 p.m. Industrial Plants II. Sponsored by the National Association of Power Engineers

Chairman: Ivan J. Cronkhite, President, National Association of Power Engineers.

Co-Chairman: Donald J. Renwick, Associate Professor of Mechanical Engineering, Michigan State University, East Lansing, Mich.

a. The Economics of Air Preheat on Industrial Boilers. Charles L. Brown, The Air Preheater Corporation, New York, N. Y.

b. New Developments in Fuel Burning Equipment for Industrial Boilers. A. W. Jackson, The Babcock & Wilcox Company, Barberton, Ohio.

c. Solving Maintenance Problems.

1. Paper by K. R. Hodges, Sears Roebuck & Company, Chicago, Ill.
2. Panel Discussion of Questions Submitted by Audience.

Panel Members: M. Berg, Allied Valve Renewal Company, Chicago, Ill.; M. B. Golber, Armour and Company, Chicago, Ill.; L. J. Cohan, Combustion Engineering, Inc., New York, N. Y.; L. J. Dawson, Ingersoll Rand Company, New York, N. Y.; S. E. Sparks, Viscosity Oil Company, Chicago, Ill.; W. R. Jacobs, Westinghouse Electric Corporation, Chicago, Ill.

2:00-5:00 p.m. Feedwater Circuit

Chairman: Roy Sahlstrom, Faville Le Vally Corporation, Chicago, Ill.

Co-Chairman: Sidney Mayster, Sargent & Lundy, Engineers, Chicago, Ill.

a. Thermal Density Currents and Their Utilization in Condensing Water Design. Rex Elder, Hydraulic Data Branch, Division of Water Control Planning, TVA.

b. Velocity Versus Pipe Size in Feedwater Systems. L. H. Carr, Director of Research and Engineering, Edward Valves, East Chicago, Ind.

c. Condenser Arrangement for Dumping Large Quantities of Steam. R. A. Wilson, Consulting Engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

2:00-5:00 p.m. Computers And Network Analyzers

Chairman: L. M. Haupt, Professor of Electrical Engineering, Agricultural and Mechanical College of Texas, College Station, Tex.

Co-Chairman: Everett B. Eggers, Research Engineer, Illinois Institute of Technology, Chicago, Ill.

a. Computers as Aids to Power System Analysis. Charles Concordia and F. J. Maginniss, Electrical Utility Engineering, General Electric Company, Schenectady, N. Y.

b. Simplified Digital Short-Circuit Solution of Power System Networks. Martin J. Lantz, Electrical Engineer, Bonneville Power Administration, Portland, Ore.

c. Patchboards on Network Analyzers. John I. Ykema, Manager, Network Analyzer Section, I-T-E Circuit Breaker Company, Philadelphia.

d. New Equipment for Network Analyzer Operation. L. E. Lingo, Supervisor, Network Analyzer Laboratory, Syracuse University.

e. Recent Improvements on the Network Analyzer. P. M. Anderson, Network Analyzer Supervisor, Iowa State College, Ames, Iowa.

f. Network Analyzer Installations in Canada and the United States. Eric T. B. Gross, Professor of Power Systems Engineering, Illinois Institute of Technology, Chicago, Ill.

2:00-3:00 p.m. Electric Space Heating

Chairman: Ole A. Hill, Jr., Marketing Supervisor, Commercial Industrial, Commonwealth Edison Company, Chicago, Ill.

Co-Chairman: Donald H. Madsen, Associate Professor of Mechanical Engineering, State University of Iowa.

a. Experiences with Commercial and Industrial Heating with Electricity. G. Gill Freyder, Engineer, Heating and Air Conditioning, Commonwealth Edison Company, Chicago.

b. Residential Electric Heating. J. H. K. Shannahan, Assistant Vice President, American Electric Power Service Corporation, New York.

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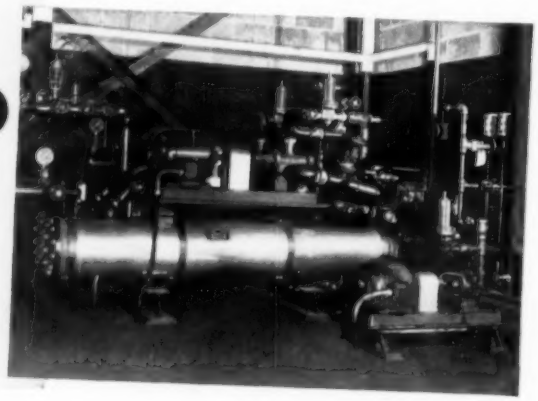

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EC-507

Abstracts From the Technical Press—Abroad and Domestic

(Drawn from the Monthly Technical Bulletin, International Combustion, Ltd., London, W. C. 1)

Fuels: Sources, Properties and Preparation

Pyrolysis of Coal and Shale. C. H. Prien and M. Perch. *Ind. Engng. Chem.* 1958, **50,** Part II, (Sept.) 1401–5.

The annual review of literature dealing with coal pyrolysis (mechanism, kinetics, thermo-chemistry), low and high temperature carbonization, oven operation, products and by-products, and oil shale pyrolysis.

Carbon Steam Reaction Kinetics from Pilot Plant Data. W. G. May, R. H. Mueller and S. B. Sweetser. *Ind. Engng. Chem.* 1958, **50,** Part I (Sept.) 1289–96.

The analysis of data from a pilot plant for the gasification of coke in a fluid bed has been used to provide information which permits the design of fluid gasification vessels for a wide range of pressure, temperature and inlet gas composition.

Coal Handling in Small Installations. R. L. Brown and J. C. Richards. *BCURA Monthly Bulletin* 1958, **32** (Sept.) 359–70.

This review deals with the physical aspects of a flowing granular mass and the various theories put forward to account for the observed phenomena, and the treatment of coal to improve its flow. It is concluded that too little is known as yet to produce a generally valid theory or to give advice to the smaller industrial user.

Steam Generation and Power Production

Use of Models for Studying Flow Processes. Anon. *BCURA Quart. Gaz.* 1958, No. **35,** 5–9.

Techniques for 2- and 3-dimensional flow visualization and their application to the study of flow patterns in a firebox and ashpan of a locomotive boiler, a cyclone combustion chamber and a fixed bed gasifier are described.

Dropwise Condensation of Steam. L. C. F. Blackman. *Research* 1958, **11** (Oct.) 394–400.

A review is presented of the work done at various British laboratories in developing promoters of dropwise condensation and the results achieved so far. These are very promising, but more research is required before industrial application can be seriously considered.

Gas Content of Steam and Boiler Feedwater. W. B. Bartley and E. Moult. *Engineer* 1958, **206** (Sept. 26) 484.

Experiments at Brunswick Wharf Power Station to determine the CO_2 content of the steam by means of a Straub degassing condenser and an infra-red gas analyser for CO_2, have shown that it is possible to work with a full scale of 3 parts by weight of CO_2 in 10⁸. The concentration of CO_2 in the steam during a 48 hour test period varied between 1.8 and 2.1 parts in 10⁸. Experiments on measuring the CO_2 concentration in feedwater are to follow.

The Preheating of Steam Pipelines. W. J. Kaufman. *B.W.K.* 1958, **10** (Sept.) 428–33 (In German).

A mainly graphical method is described for determining the additional stresses caused in pipelines during starting up. The flow velocity, heat transfer to the wall, wall thickness and material composition are taken into account. The sudden intensive heat transfer during condensation is treated and measures discussed to avoid excessive stresses in this case.

Experimental Data on Metal Temperature Conditions of Horizontal and Slightly Inclined Boiler Tubes. Z. L. Miropolskii and R. I. Shneerova. *Teploenergetika* 1958, **5** (June) 56–60 (In Russian).

Results are given as obtained from experimental data on temperature conditions in the metal of tubes of various diameters with pressures of 36–220 atm abs, heat flows of 30,000–230,000 kcal/m²h, and unilateral uniform heating. The process of generalizing the data with the aid of dimensionless criteria is explained. Twelve references are appended.

From C.E.G.B. Digest 1958, **10** (Oct. 25) 2881.

Starting Diagrams and Charateristic Tube Graphs in Quick Starting of Forced-Flow Boilers. H. Opladen. *Energie* 1958, **10** (Sept.) 362–9 (In German).

An analysis is presented of water and steam flow, pressures and temperatures in the tubes of a forced flow boiler during quick starting and the conditions in which instability of flow in individual tubes may occur. An example shows that at a high starting pressure uncontrollable increases in pressure may occur, which would endanger the boiler plant; at low pressure flow instabilities may occur. The starting pressure is therefore to be chosen carefully.

Furnaces and Combustion

Some Investigations with a Small Cyclone Combustor. H. R. Hoy, A. G. Roberts and D. M. Wilkins. *J. Inst. Fuel* 1958, **31** (Oct.) 429–57.

The research carried out by BCURA on a small cyclone combustor (3 ft dia and 3 ft high) is summarized. The main factor in the operation was the temperature viscosity of the slag which is characterized by the silica ratio of the ash. If this ratio exceeded 72, operation became impossible. The analysis of the ash of a large range of untreated smalls suggests that large tonnages of this type of coal could be used for cyclone firing. The report includes a description of the cyclone temperature, test rig, test program, performance (effect of velocity and heat input, secondary air velocity), effect of fuel/air ratio, secondary air temperature, fuel size and type, deposits and corrosion. The application of the combustor to the open-cycle gas turbine and boiler firing is discussed.

Thermal Losses in Firing Low-Grade Fuels. E. Hoffbauer. *Energie* 1958, **10** (Sept.) 376–7 (In German).

The thermal losses in slag tap furnaces consist of the unused heat content of the slag and the heat required to reduce the moisture content of the fuel to 0.5 per cent. A table and a nomogram facilitate the calculations. The monetary loss depends on the fuel costs which generally vary with ash content and calorific value.

Water-Side Corrosion and Water Treatment

Boiler Water Treatment of Steam Generators up to 300 psi Operating Pressure. Anon. *B.W.K.* 1958, **10** (Oct.) 488–92 (In German).

The main points of the recently issued revised specifications are reproduced.

Some Relations between Deposition and Corrosion Contamination in Low Makeup Systems for Steam Power Plants. E. S. Johnson and H. Kehmna. *Corrosion* 1958, **14** (Sept.) 49–54.

It is shown that mechanisms based upon the thermodynamics of the soluble ions from the corrosion of materials of construction can qualita-

tively account for both the form and composition of the deposits from high purity water in large steam generating stations. The ratio of copper to iron seems more important than the absolute concentration of either. Small variations in the concentration of other ions do not seem to be of any great importance.

From authors' abstract

Radioactive Water Poses New Problems. C. T. Dickert, R. Hetherington and C. F. Raines. *Power* 1958, **102** (Sept.) 88–90.

The reasons for the high purity of water required for use in pressurized water reactors are discussed by showing the conditions to which the water is exposed inside the reactor. The effects of irradiation and the presence of oxygen in the water both cause corrosion and corrosive deposits and fission product poisons further aggravate the problem.

Corrosion and Water Purity Control for Army Package Power Reactor. R. J. Clark and A. L. Medin. *Corrosion* 1958, **14** (Sept.) 39–43.

The primary purification system of the pressurized water circuit is described and performance data given. Coolant resistivity was maintained above 600,000 ohm cm and pH averaged 7.5–8.5. The corrosion rate has so far been less than that estimated at 0.05 mg/cm² mo.

From authors' abstract

Flue Gas, Ash and Dust

The Prevention of Air Heater Corrosion. L. E. Hardy. *Steam Engr.* 1958, **28** (Oct.) 20–1.

It is proposed that the air for oil fired boilers be prehated by exchange with water from a special low temperature economizer, before being passed to the fuel gas heated air heater. It is argued that cast iron is less susceptible to corrosion by sulphuric acid and sodium, because the metal temperature will be more uniform and that it is easier to clean.

Power Generation and Power Plant

The Montreal Power Conference. Anon. *Engineer* 1958, **206** (Sept. 26) 486–7, (Oct. 3) 520–3, (Oct. 10) 559–62.

The first part reviews papers dealing with hydroelectric power, pumped storage and hydraulic machinery, the second with coal (extraction, handling, use of low grades, gasifiction), oil and gaseous fuels and nuclear energy, the third with turbogenerating sets, heat-electric stations, combined gas and steam turbine cycles, fuel efficiency, geo thermal power, transportation and utilization.

Steam-Gas Cycle with Additional Combustion. Anon. *Engineer* 1958, **206** (Oct. 10) 570–2.

Abstracts of a paper by V. Kral to the Montreal World Power Conference are presented. A combined gas and steam turbine cycle is described in which a separate combustion chamber is used to reheat exhaust gases passed to the boiler for superheating the steam. The effect of a large number of variables (steam parameters, initial gas entering temperature, compression ratio, aerodynamic qualities, fuel for gas turbine and boiler firing, auxiliaries efficiency) on overall efficiency is considered and the efficiencies for a series of given conditions are calculated. It is shown that small units of 25 MW can operate at efficiencies as high or higher than much larger units on either gas or steam alone, and that the efficiency curve is very flat over a large load range.

Industrial Plant Design Survey. Anon. *Power* 1958, **102** (Oct.) 105–20.

The survey of recent industrial plant installations details: 1. Electrical systems; 2. Capacity and size of boilers, firing methods and heat release; 3. Turbine types and sizes; 4. Controls; 5. Feedwater treatment; 6. Typical power plant; 7. Typical packaged boiler installations.

Central Station Design Survey. Anon. *Power* 1958, **102** (Oct.) 173–88.

Block diagrams and tables give details of recently commissioned boilers, turbines, and ancillary plant and those under construction with regard to boiler ratings, furnace heat release rates, steam parameters, turbine capacities, fuels and firing equipment and controls. No major changes from previous survey trends have become apparent. Design details of experimental and commercial nuclear plants and hydroelectric stations in U.S.A. and Canada are also included.

Top Efficiency Station. Anon. *Elec. Times* 1958, **134** (Oct. 23) 632–3.

Castle Donington power station was officially opened in October 1958. During 1957–8 it had the highest efficiency (32.16 per cent) of all British stations. When completed in 1959 it will contain six pulverized coal fired twin-furnace boilers each rated at 830 klb/h, 1500 psi and 1050 F and six 100 MW turbogenerators. Each boiler is supplied by four pressure-type ball mills (plus one reserve) each rated at 25,000 lb/h serving twenty burners in the furnace front wall. Ash disposal is hydraulic. Each pair of boiler-turbine units are controlled from a central plant control room, the station control room being in a separate building.

Planning and Construction of the Power Station II of the Duisburg Municipal Works. H. Ehrig. *B.W.K.* 1958, **10** (Oct.) 453–65 (In German).

This power station has been erected in the center of an industrial, commercial and residential district to supply both electric power and hot water (100 C) for central heating. Extensive calculations showed the most economic solution to be a 64 MW unit with an extraction point at 22 psi for 100 klb/h of steam for the hot water heat exchangers. The steam is generated in a natural circulation boiler rated at 500 klb/h at 2500 psi and 985 F with reheat to 985 F, air preheat to 750 F and flue gas exit temperature of 285 F. The coal (20 per cent ash, 12 per cent moisture, 20 per cent V.M., melting point 2730 F) is pulverized in two 18 t/h mills with a mixture of recirculated combustion gases (1835 F) and mill vent gases, stored in an intermediary bunker and fired in a horizontal cyclone. Fly ash from the boiler passes and combined electrical-mechanical separator is refired. Temperature control of both the superheated and reheated steam is by spray desuperheaters and flue gas bypass. The boiler has a guaranteed thermal efficiency of 92 per cent. The turbine has seven extraction points for preheating the feedwater and a heat rate of 6800 Btu/kWh. The generator is hydrogen cooled at 15 psi. The controls for the boiler and turbine are also described.

New Power Stations of Düsseldorf. W. Cautius and A. von Weihe. *B.W.K.* 1958, **10** (Oct.) 475–81 (In German).

The town of Düsseldorf is supplied with electric power from 5 power stations. Lausward contains one 85 MW and one 135 MW unit with steam at 2200 psi and 980 F with reheat to 960 F providing the base load, Flingern I with two units of together 110 MW with steam at 1320 psi and 980 F for medium loads, Flingern II of 70 MW capacity with steam at 660 psi and 840 F for peak loads, and some older power stations, with together 30 MW capacity for reserve. Each of the units at Lausward station is, for various reasons stated, served by two natural circulation boilers provided with cyclone furnaces for the firing of bituminous and brown coal and oil in any proportions. The pulverized coal is stored in intermediary bunkers, because in this way the exact coal-air ratio (1.05 per cent excess air) can best be kept constant at all loads; the mill vent gases are re-injected into the tertiary furnace, the fly ash from the electrostatic precipitator into the cyclone or secondary furnace. Primary

ash retention in the cyclone with coal pulverized to 70 per cent residue on the 0.1 mm screen is 80 per cent. No soot blowers are installed and the steel shot cleaners installed in the convection heating surfaces are not required. The steam of the first unit is expanded in a 25 MW topping turbogenerator (50 c/s), reheated at 360 psi and then passed to one 25 MW turbogenerator operating at 16⅔ c/s for railway traction and one 50 MW turbogenerator operating at 50 c/s.

Ferrybridge "B." Anon. *Elect. Rev.* 1958 **163** (Oct. 3) 603–10.

This station near Pontefract, Yorkshire, will contain 3 units, each consisting of a boiler rated at 760 klb/h at 1600 psi and 985 F with reheat to 955 F and a 100 MW turbogenerator. The measures taken to reduce building volume to 31 cu ft/kw and station costs to £49/kW installed capacity, are outlined and the description includes the coal and ash handling plant, steam generators and ancillary plant, turbines and generators and the cooling water system.

Preheat at West Penn. G. I. Smith. *Heat. Engng.* 1958, **33** (June/July/Aug.) 144–7.

At the Armstrong Station of West Penn Power Co. the first of two 165 MW units started operating in April 1958. The steam generators are each rated at 1200 klb/h at 2250 psi and 1010/1010 F with a guaranteed efficiency of 87.95 per cent. The furnace front wall and roof are constituted of superheater tubes, the other walls of evaporating tubes; the furnace is divided into two parts along its center line. Superheated steam temperature is controlled by spray desuperheaters, reheated steam temperature by a gas bypass. The twelve burners (6 × 2) in the front wall of the furnace are served by two ball mills designed to handle 166,000 lb/h of coal.

Alcoa's Plans for Trend-Setting Use of Aluminum in the Power Services. Anon. *Power* 1958, **102** (Oct.) 78–81. The power station at the new Warrick aluminum producing plant of Aluminum Co. of America is one of the largest industrial stations built in recent years and also a demonstration plant for the use of aluminum in power services. The three outdoor boilers are each rated at 1000 klb/h at 1975 psi and 1005/1005 F and contain 16 pulverized coal burners supplied by four mills with steam temperature control by flue gas recirculation and spray attemperation. Three 125 MW turbogenerators supply the electrical load. Aluminum is used for the condensate storage tank and to a large extent in the electrical circuits.

Bound Brook Puts Plan '59 in Action to Modernize, Prepare for Future Growth. Anon. *Power* 1958, **102** (Oct.) 92–5.

The new single-cyclone fired boiler rated at 200 klb/h at 865 psi and 825 F has been installed to supply a 7500 kW turbo-generator operating against a back pressure of 125 psi. The boiler has a pressurized furnace, air preheater and economizer being placed below the convection bank to save building space. There is an electrostatic precipitator and hydraulic ash handling system. Since no condensate is returned, a 100 per cent make-up is required which is treated in a hot lime-zeolite unit.

Great Northern Paper Adds New Plant for Process Steam and Power. R. V. Weldon and W. E. Knight. *Power Engng.* 1958, **62** (Sept.) 86–9.

At these works three oil-fired C.E. boilers each rated at 300 klb/h at 300 psi and 855 F and two 18 MW turbogenerators have been installed, the generators being hydrogen cooled (30 psi). The first turbine is operating against a back-pressure of 210 psi which can be increased to 250 psi; the second is a double extraction condensing turbine with extraction at 210 (250) psi and 40 (50) psi. A special feature is the provision that surplus process steam can be fed back to these extraction points and passed through the lower pressure stages of the turbine to the condenser to increase the electrical output. Neutral amines are added to the feedwater to protect the condensate circuit against corrosion and copper and iron pick up. Provision is also made for coal firing by installing coal handling facilities, bunkers, pulverizers, fly ash collectors and ash disposal equipment, if coal should become cheaper than oil.

Experiences in two 600 C High Pressure Power Stations of the Feldmühle Papier-und-Zellstoffwerke A.G. F. Wehrberger. *B.W.K.* 1958, **10** (Oct.) 466–74 (In German).

The two works Reisholz and Arnsberg contain two Benson boilers each. In the former they are rated at 140 klb/h at 2400 psi and 1120 C, in the latter at 130 klb/h at 2600 psi and 1130 F, all provided with slagging furnaces of different designs. In all furnaces difficulties arose with the removal of the liquid slag as soon as coals with ash of high fusion temperature (especially American) were used. Blending of coals with different ash properties solved this problem. Deposit formation in the upper part of the furnaces was also experienced and this was reduced by increasing the pressure of the secondary air and by water washing. Other difficulties relating to the starting up of the boilers, cracks on flanges, troubles in the mills, bunkers and filters, feedwater controls and valves, slag transport, turbines, boiler controls, pipelines and pumps are described. The scheme worked out for starting and stopping the boilers and turbines is outlined. It is concluded that after overcoming most difficulties both works have reached the expected economics.

Packaged Boiler Meets Process and Power Needs. C. K. Stickney. *Combustion* 1958, **30** (Sept.) 38–41.

The Scovill Manufacturing Co. has installed a packaged C.E. boiler rated at 100 klb/h, 660 psi and 750 F, because of its ability to follow closely frequent swings of load, quick starting and small space requirements (13 ft wide × 34 ft deep × 13½ ft high). Operating experience has been excellent, especially the fact that the temperature is held constant from half load to full load under all operating conditions.

Nuclear Stations in Britain's Power Program. Comparative Costs Forecast at Geneva. Anon. *Elect. Times* 1958, **134** (Sept. 18) 423–4.

Brief abstracts of 3 papers are presented by J. C. Duckworth and E. H. Jones, W. Strath and J. Jukes, respectively, dealing with attempts to forecast the cost of electricity generated by nuclear power stations and their comparison with those from coal fired stations. It is believed that those nuclear stations to be completed by 1962 will generate only very slightly above the cost of coal fired stations, where fuel costs are high, ie., 0.59–0.70d against 0.64–0.65d.

Project for a Nuclear Heating and Power Plant of 30,000 KW Thermal Output. A. F. Fritzsche and P. de Haller. *Sulzer Techn. Rev.* 1958, **40** No. 3, 5–14.

For the extension of the district heating and power station of the Swiss Federal Institute of Technology in Zurich, an underground nuclear power station is planned which is to contain a heavy water moderated and cooled reactor including the pressurized tube principle in which the coolant and moderator are separated by a pressure carrying wall. The cooling water is pressurized to 860 psi, enters at 190 C and leaves at 220 C; the moderator water is at atmospheric pressure and a temperature of 50 C; its heat uptake is not utilized. The moderator aluminum tank is surrounded by a graphite reflector. The main fuel is natural uranium (5 ton), but in an outer annular zone a small number of enriched (1%) U235 elements are arranged. In the coolant heat exchangers 88,000 lb/h of steam at 160

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psi and 360 F are generated which are passed either to 2 condensing turbo-generators with a total output of 5900 kW or divided between these and a calorifier with a capacity of 20 t/h producing saturated steam at 100 psi for the district heating system. The layout of the building, reactor and fuel elements are described.

Materials and Manufacturing Processes

Nickel, Including High-Nickel Alloys. A. J. Marron. *Ind. Engng. Chem.* 1958, **50,** Part II, (Sept.) 1460–9.

The annual review of literature is sub-divided into: 1. Physical metallurgy, research and development; 2. Application; 3. High temperature application; 4. Welding and fabrication.

Stainless Steels and Other Ferrous Alloys. W. A. Luce and J. H. Peacock. *Ind. Engng. Chem.* 1958, **50,** Part II, (Sept.) 1482–8.

The annual review of literature is divided up into: 1. Corrosion; 2. Mechanical properties and structure; 3. High temperature; 4. Welding; 5. General (manufacture, metal working, surface treatment); 6. Miscellaneous iron-base alloys.

The Effect of Alloying Elements on Creep Behavior. J. Glen. *J. Iron & Steel Inst.* 1958, **190** (Oct.) 114–35.

Structural changes occur in commercial alloys during creep testing which are of the strain-age-hardening or strain-induced precipitation type. These changes appear as transitions in creep rate, a sudden deceleration of the rate over an interval of time. A theory is put forward to account for this phenomenon. Data show the effects of N, C, Mn, Cr, Mo, V, Ti and Si on creep resistance of steel.

The Corrosion Resistance of Ductile Iron. F. L. LaQue. *Corrosion* 1958, **14** (Oct.) 55–62.

The internal structure of rodinary gray iron, pearlitic ductile iron, malleable iron and mild steel are compared and their differences in corrosion behavior explained. The results of the tests in a variety of corrosive media and of exposure conditions and the measured corrosion rates are presented. It is concluded that ductile iron can often be used as a substitute for gray and malleable iron and steel and in some cases has shown superior corrosion resistance.

The Corrosion Behavior of Zirconium-Uranium Alloys in High Temperature Water. W. E. Berry and R. S. Peoples. *Corrosion* 1958, **14** (Sept.) 34–8.

The effect on corrosion behavior of water temperature, uranium content

and oxygen content has been determined for Zr 7-70 weight per cent uranium alloys. Corrosion rates increased with increase in water temperature from 500–580 F, uranium alloy content and oxygen content.

From authors' abstract.

Welding Low-alloy Steel Castings for High Pressure and High Temperature Service. N. A. Chaplin, C. H. Soldan and L. W. Songer. *Weld. J.* 1958, **37**, (Oct.) 979–87.

Design requirements, weld preparation, preheat and postheat treatment, intermediate stress relief, welding techniques, (stop-pass, transition) and non-destructive testing are described.

Report from Geneva. Anon. *Nucl. Engng.* 1958, **3** (Oct.) 419–48.

Brief summaries and lists of papers submitted to the Geneva Conference are presented under the headings: 1. National Power Programmes (419–21); 2. Nuclear Fuel Resources (422); 3. Thermonuclear Research (423–7); 4. Interesting Reactor Designs (428–31); 5. A Survey of Water Reactors (435–7); 6. Fast Reactors (437–9); 7. Liquid Metal Technology (439–40); 8. Gas-cooled Power Reactors (440–1); 9. Nuclear Materials (443–8).

Atomic Review—Three Questions. Anon. *Engineering* 1958 **186** (Oct. 17) 504–5.

The three questions put to Dr. N. Hilberry of the Argonne National Laboratory were: 1. Instability in boiling reactors; this problem has proved to be unreal; 2. Boiling heavy water; there are no special snags in this type; 3. Gas cooled reactors; The U. S. Atomic Energy Commission is holding a conference at which five types of gas cooled reactors will be considered. Three of the designs and cost studies to be presented, are outlined briefly.

Light Water or High Pressure Gas Cooling for a 100 MW Reactor Project. H. Kornbichler. *Atom & Strom* 1958, 4 (Sept.) 71–6 (In German).

Two projects have been studied by the A.E.G. in recent years, one a dual-cycle boiling light water and the other a pressurized gas cooled reactor with ceramic fuel elements for the latter. Since the light water moderated and cooled reactor requires enriched uranium fuel, it is planned to use natural uranium and heavy water as moderator in the pressurized gas cooled reactor, but calculations have also been carried out for using graphite as moderator and slightly enriched uranium. Both the heavy water and graphite moderated reactors would produce electric energy at the same cost (4 Dpf kWh), less than a light water moderated reactor.

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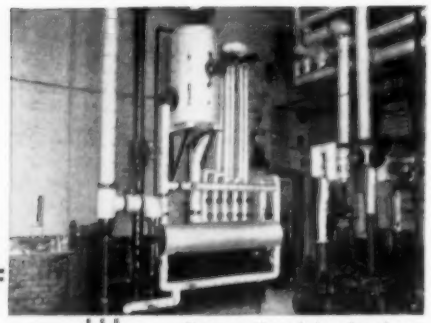

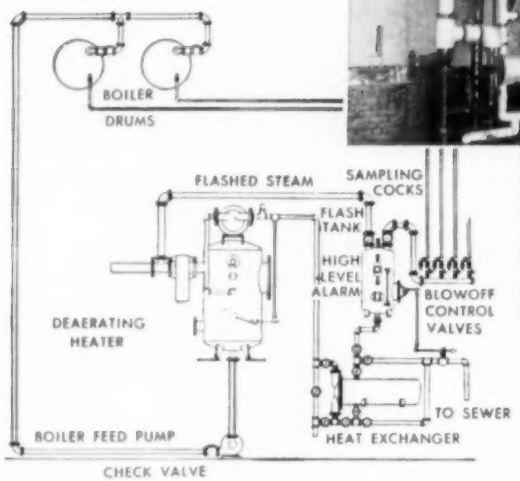

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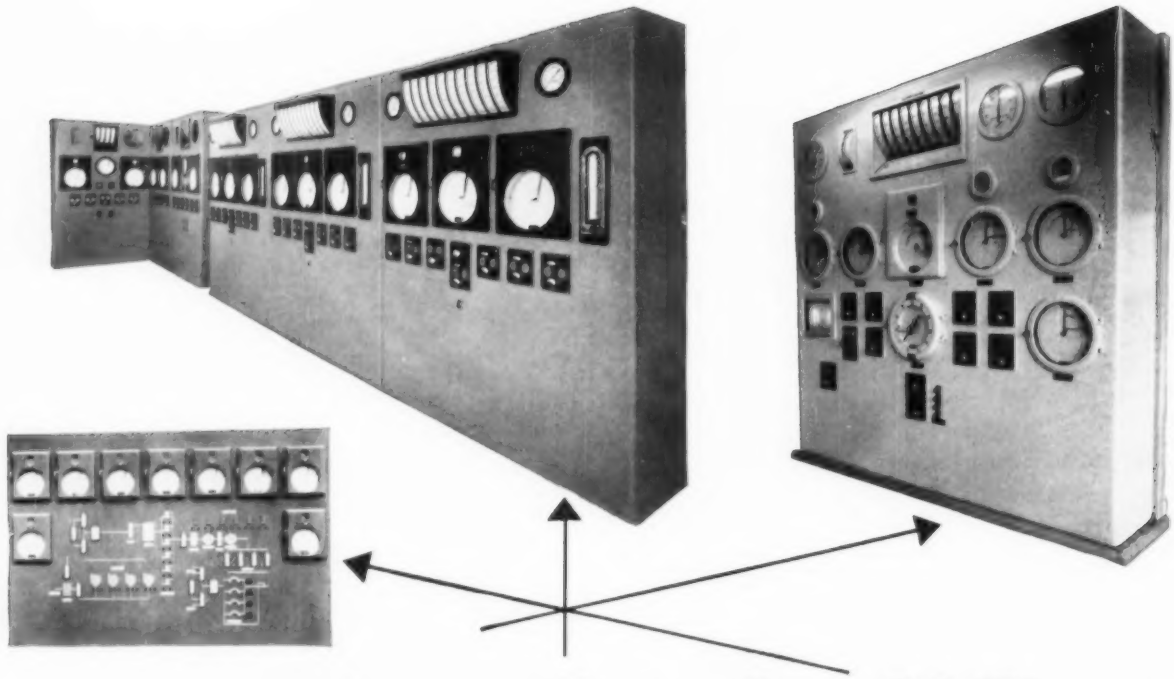

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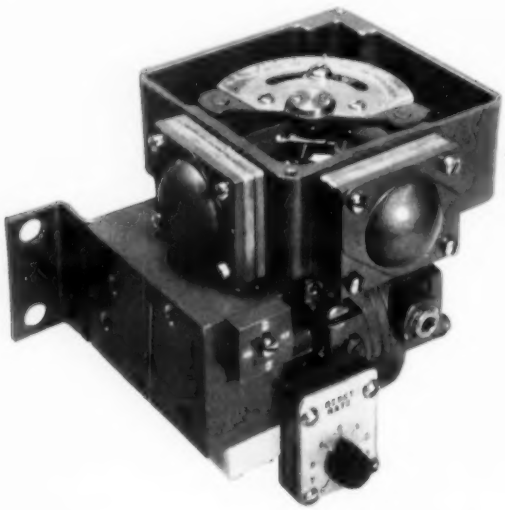

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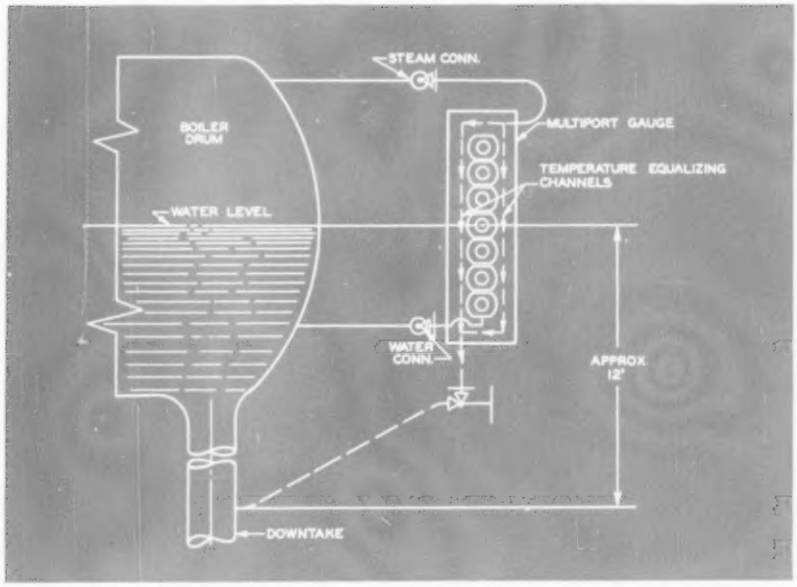

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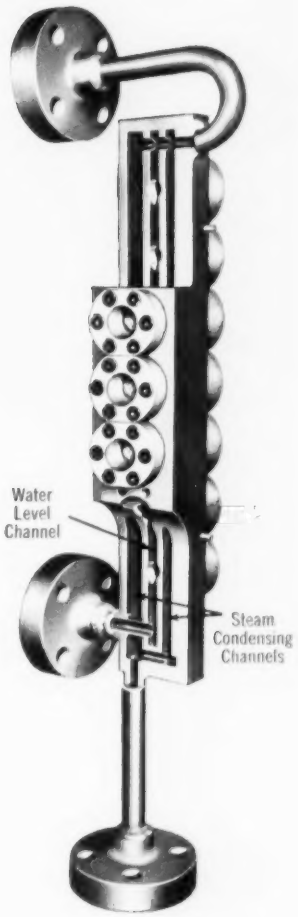

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